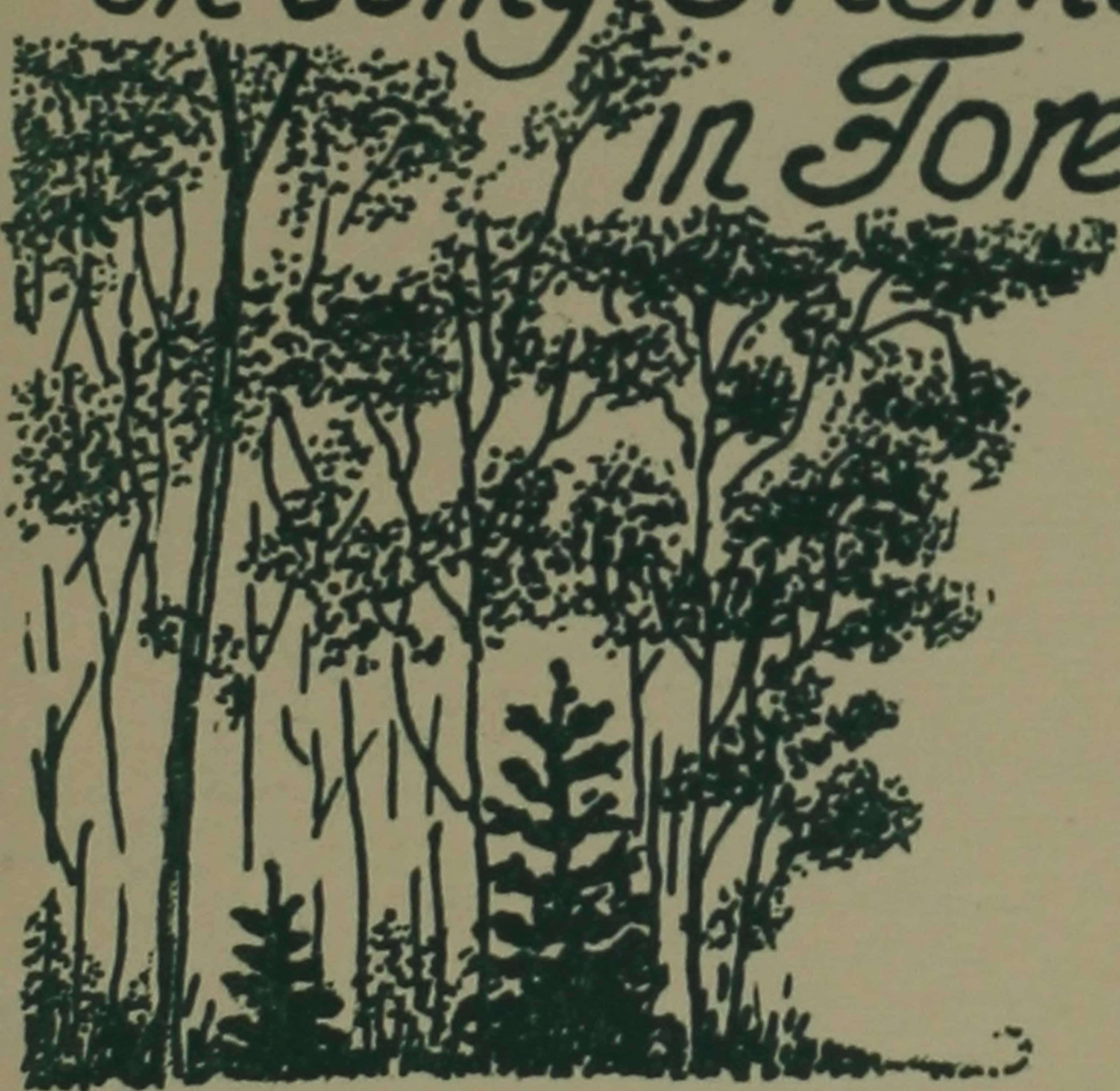
Proceedings Lake States Forestry Clinic on Using Chemical Controls in Forest Management

Feb. 10 & 11, 1953



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Lake States Forest Experiment Station

Miscellaneous Report No. 21.

FOREWORD

Early in 1952 the Industrial Foresters Research Group — which includes foresters from most of the pulp and paper companies in the Lake States — met in Minneapolis, Minnesota. At that time the group expressed considerable interest in chemical control of woody plants and requested the Lake States Forest Experiment Station and the Minnesota School of Forestry to arrange a meeting on that subject for 1953. As a result, the following program was developed and presented.

To provide a record of this conference for those who attended it and to make its deliberations available to others, we have issued this proceedings. We wish to express our appreciation to all those who took part in the program, especially those who represented other organizations or came from a considerable distance. We were pleased with the fine attendance and the excellent participation in the discussion periods.

BRUCE BUELL
Industrial Foresters
Research Group

M. B. DICKERMAN
Director, Lake States
Forest Experiment
Station

FRANK KAUFERT
Director, School
of Forestry,
University of
Minnesota

U.S.D.A. S.C.S., Milwaukee, Wis., 1953

LAKE STATES FORESTRY CLINIC

PROGRAM AND TABLE OF CONTENTS

Subject: Using chemical controls in forest management.

Place: Auditorium, Green Hall, University Farm, St. Paul, Minn.

February 10, 1:30 p.m.

Chairman: Bruce Buell, Lake States Industrial Foresters Research Group

February 11, 8:30 a.m.

Chairman: Frank Kaufert, Division of Forestry

CHEMICAL BRUSH CONTROL - WHAT IT IS

R. H. Beatty
American Chemical Paint Company

Modern chemistry plays a larger part in our lives every year. In forestry this is just as true as with textiles or foods.

In 1944, two chemicals -- 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) -- were introduced. They have radically changed our approach to the brush control problem in this country. Before 1944, most brush control was mechanical, although there was limited use of such chemicals as the chlorates, dinitro cresol compounds, soluble arsenicals, copper sulfate, ammonium sulfamate and other compounds. With the exception of ammonium sulfamate (ammate), these compounds have been replaced by 2,4-D and 2,4,5-T in chemical brush control.

It is estimated that in the United States nearly 4,000,000 pounds of 2,4,5-T acid were produced last year, all for use in controlling woody plants. Further, most of our brush-killer formulations contain at least 50 percent 2,4-D acid equivalent so it is evident that in this country many million pounds of these phenoxy acids are being used to kill brush along electric transmission and distribution lines, along railroad right-of-ways, and on millions of acres of range land, to mention only a few of the utilizations.

The advantages inherent in 2,4-D and 2,4,5-T gave a tremendous stimulation to the workers in this field and now act as guides in the development and evaluation of new chemicals.

The phenoxy acids are not toxic to humans or wildlife at concentrations used in controlling woody plants. Their selectivity in controlling these plants and broadleaf weeds with little or no injury to conifers is unequalled. Because of their effectiveness at very low concentrations the phenoxy acids have made possible low volume airplane spraying.

Even with these desirable properties, the wide acceptance of phenoxy compounds would not be justifiable if it were not for their low cost to the user.

Foresters are using the growth regulators and ammonium sulfamate in increasing amounts in the pine forests to eliminate undesirable hardwoods which suppress the young pines and in plantations of conifers to combat competition from invading woody plants. The <u>Ribes</u> species so essential in completing the pine blister rust cycle are being treated with these materials to help control the spread of the rust where five-needled pines occur.

We employ four major techniques in controlling woody plants chemically -- foliage spraying, basal spraying, stump treatment, and frilling.

FOLIAGE SPRAYING

The foliage spray is a growing season treatment which can be applied with ground equipment using a high volume of solution, or by airplane using economically low volume sprays. Best results are obtained after the foliage is fairly mature. Under Eastern conditions foliage spraying may be continued for a period of several months. However, certain plants, especially those in the Southwest, are best treated at very critical times during their growing season. For example, sand sage is most sensitive to 2,4-D over a very short period when the stored food reserves are at their lowest point and mesquite response is best when moisture has been adequate during the period before growth starts.

We are using three chemicals for foliage sprays -- 2,4-D, 2,4,5-T, and ammonium sulfamate. Although less selective than the phenoxy compounds, ammonium sulfamate is very effective on many woody plants which resist the 2,4-D and 2,4,5-T compounds. Its use is limited to application with ground equipment because of the large volumes of water needed. With the phenoxy compounds relatively small amounts of chemical are needed and, therefore, low volume airplane application to certain plants is practicable.

The particular chemical used is determined largely by the plant's response. In the case of willow, 2,4-D is most effective while thornapple responds best to 2,4,5-T. When mixed species are present, a combination of 2,4-D and 2,4,5-T or ammonium sulfamate would be indicated, depending on plant sensitivity.

2,4-D and 2,4,5-T are formulated for use on woody plants as "low volatile" esters or as oil-soluble acids. The two most commonly used esters are the propylene glycol butyl ether ester and the butoxy ethanol ester. These esters have replaced the short-chain alkyl esters such as butyl, ethyl, isopropyl and others originally used because they are equal or greater in effectiveness and they do not have the same degree of "phytotoxic" volatility. Under some field tests, acid formulations have been even safer than the low volatile esters with respect to vapor damage and equal to the esters in their ability to translocate in the plants.

Although the acids in oil and the esters seem to be more effective on woody plants because of their apparent ability to penetrate the cuticle of the leaf, we continue to be interested in non-toxic oil foliage sprays of certain amine salts of the phenoxy acids having an affinity for water after entering the plant. The water soluble esters such as the polyethylene glycol type are showing promise under California conditions and warrant further study.

Although foliage sprays with our present formulations are effective on many woody plants there are several such as ash, red maple, basswood, beech, and certain oaks which do not respond with root suppression or even top kills in some cases. Increasing the amount of acid in the solution often gives poorer results instead of improving them. One answer to the problem may be more frequent applications of the phenoxy acids at lower concentrations.

From available data it seems important that foliage sprays of the phenoxy compounds be applied when the stored food supply is lowest, when the leaves are of medium age, and when the plants are replenishing their food reserves.

Timing sprays to take advantage of these data on translocation can be done rather readily with most woody plants, but becomes quite difficult with plants which replenish their food reserves over a very short period, or as with some arid woody plants only when they are sensitive to growth regulators because of suitable moisture and temperature conditions.

Besides these factors which affect the transport of the phenoxy compounds we are confronted with the extensive root systems of many plants. These plants apparently maintain a large amount of stored food which is a factor in determining the ability of the plant to resprout after the top has been killed.

With many woody plants the phenoxy compound will kill the above-ground portion, but how far the effect of these chemicals extends past the root-stem transition zone in some species is still unknown. Our ability to kill these woody plants seems to depend upon such factors as the amount of stored food, the area in which dormant buds are located, the amount of chemical the leaves will absorb and transport, and the sensitivity of the plant to the particular phenoxy compound.

Recent tests, using a radio-active isotope incorporated in a morpholene salt of 2,4-dichloro-5-iodophenoxy acetic acid, indicated that in no case did more than 2.5 percent of the material deposited on the leaves of mesquite seedlings move downward. This downward movement of the phenoxy acid or its breakdown products in woody plants, particularly when it reaches the root-stem transition zone needs further investigation and is the most important single problem confronting research workers in this field today.

In an effort to overcome these foliage treatment failings on certain plants, we have endeavored to increase penetration by using various additives with the phenoxy compounds. Results of these tests indicate that the addition of small amounts of oil to the water spray will increase top kill and root suppression on many of our plants which have not responded to the formulations now used in foliage spraying. By using small amounts of oil in this manner we believe we are increasing

penetration and not interfering with translocation as expected by many workers, but are actually increasing top kill and root suppression of many resistant plants.

The amount of oil used in the spray solution will vary with species, leaf susceptibility, and stage of growth when treated. Under Eastern conditions with mixed species the addition of 10 percent oil in the water solution has been most effective over the past two years. The addition of such adjuvants as sodium trichloro acetate and ammonium fluosilicate to the water solutions of 2,4-D and 2,4,5-T to increase top kill has given results which are most encouraging.

When using other chemicals with the phenoxy compounds the most important factor is the amount of chemical used in the spray solution, as high rates may produce inhibition of the herbicide rather than activation. Certain chemicals such as indole acetic acid may inhibit the action of phenoxy compounds. Others such as trichloroacetic acid may increase the action of the phenoxy compounds. Much more work is needed on the use of adjuvants.

Another approach to making foliage sprays more effective on a greater range of species is trials of other growth regulators. 4-chlorophenoxy acetic acid and 2-methyl-4-chlorophenoxy acetic acid possess selective killing properties which have not been fully evaluated on woody plants.

As an illustration of the selectivity toward species within the same family, it has been noted that certain species of barberry are most sensitive to 2-methyl-4-chlorophenoxy acetic acid, while other species respond best to 2,4-D and still others 2,4,5-T. There is no way to predict the response to the different phenoxy acids and more field trials are needed with the 4-chlorophenoxy acetic and 2-methyl-4-chlorophenoxy acetic acid, as well as other chemicals, for selectivity toward plants which are not susceptible to 2,4-D or 2,4,5-T.

BASAL SPRAYS

Although foliage spraying is the most economical approach to the problem and very effective on many species it has some shortcomings. In an effort to overcome the problems of inadequate absorption and translocation of the phenoxy compounds in plants which do not respond to foliage sprays, and to lengthen the spraying season, the basal method has been developed. This method by-passes the foliage and some of the translocation problems by applying 1- to 2-percent concentrations of the 2,4-D and 2,4,5-T esters in oil to the basal part of the plant covering all the stems from the ground line up 12 to 15 inches.

Basal sprays are most frequently used as a follow-up treatment for plants which were not killed by an initial foliage spray, or when most of the plants are known to be resistant to foliage sprays. This technique has the added advantage of being effective at any time during the year. When plants are treated with this method during their dormant period they often leaf out in the spring and then start to die from the growing point back. This method was once considered as a treatment for use during dormancy only, but five years' data have shown it to be equally effective when applied during the growing season. Red maple may be cited as an exception because it seems to be most affected when basal application is made just prior to bud swelling.

Whether the phenoxy acids are applied as esters, acid, or oil-soluble amines is not nearly as important as the volume of the carrier and the plant area sprayed. Studies indicate that the volume of material applied is the most important single factor. When a 1.5 percent by weight concentration of 2,4-D ester in oil was used, about 40 cc. per inch of diameter was necessary to suppress resprouts from the root-stem transition zone in ash. If the concentration was increased but the volume decreased the results were poor. Tests on white oak brought out that when the material was applied to the basal 15 inches of stem, the plant was dead through its entire length, but when applied to the terminal 15 inches, kill was limited to the area treated and an average distance of 10 inches below it.

The fact that one must apply the material in rather high volumes, enough to run to ground line, and that the spray must be directed to the base of the plant leads many of us to question the degree to which the chemical or its breakdown products may be translocating in the root system. We know that the material applied at the base moves upward and kills the foliage and stems above the point of application. However, we question how far the spray material affects the root system because we find that the material must collect at the base of the plant, indicating that it may primarily inhibit the adventitious buds present in the root-stem transition zone.

Although basal sprays are much more effective than foliage sprays, we still have some species such as locust, aspen and certain oaks which are difficult to eradicate with a single treatment. These plants have the ability to resprout from lateral rhizomes so repeating treatment until the food reserves are exhausted is the only method we have with the present chemicals.

Experimental basal sprays of an oil-water mixture to reduce the cost of the oil carrier, and experimental broadcast basal sprays on certain species, rather than individual plant treatment, are both promising enough to warrant further study.

STUMP TREATMENT

This involves the same principles as basal treatment, except that the top of the plant is removed and only the remaining stump is treated with 2,4-D, 2,4,5-T or ammonium sulfamate. Stump treatment is a very practical method of preventing regrowth from cut trees, especially if these trees are of inferior species that should be eliminated from the next timber crop grown on the area.

The method is effective on stumps of plants which resprout from the root-stem transition zone, but is not as effective on plants which can resprout from dormant buds on lateral rhizomes, again indicating the poor movement of the phenoxy acids in a horizontal plane and the possibility of the growth regulator's acting as an inhibitor of these dormant buds rather than actually killing the plant by translocating throughout the root system.

In treating stumps, 1- to 2-percent concentrations of the growth regulators in oil are sprayed any time following cutting. As in basal spraying, the material must be applied so heavily to the cut surface and all sides that it runs down and collects at the ground line. Many feel that 2,4,5-T is more effective than 2,4-D when this method is followed, regardless of the sensitivity of the species. Ammonium sulfamate is applied by using the dry crystals at rates of one-half pound per four inches of stump diameter, and is very effective in this type treatment.

FRILLING

This method is most useful in forest management where large trees are the problem and it is not objectionable to leave them standing after they have been killed. It requires making a frill around the trunk, with a continuous series of vertical axe cuts leaving the bark attached at the bottom. A solution of 2,4-D, 2,4,5-T or ammonium sulfamate is poured into this frill or trough uniformly around the circumference of the tree. Ammate is used as dry crystals or a concentrated solution, while 2,4-D and 2,4,5-T are used in the ester and amine forms. Some workers are using the esters in water.

In the Southeast ammonium sulfamate and 2,4,5-T have proved effective in converting mixed stands of hardwoods and pines to a valuable pine forest type. Small hardwoods can be eliminated best by using a basal spray of 2,4,5-T in oil. However, on trees of four inches or more in diameter, a frill or stump treatment is indicated. Ammate has been reported effective on nearly all species when used for frill treatment. In addition, ammate applied as crystals to notches or cups cut in the bases of trees has given good kills of undesirable woody growth. A deep cut is not necessary but the ammate must be applied as soon as the notch is made.

MORE KNOWLEDGE NEEDED

A thorough knowledge of the plants being treated is essential -- the time when food reserves are lowest, the period during which food materials are being transported, the selectivity of the acids toward the plants to be treated, and the area from which the plant can re-sprout, whether it be from the root-stem transition zone or from dormant buds on lateral rhizomes.

The two most pressing problems needing more research are the effect of the phenoxy compounds or their breakdown products on the dormant buds in the root-stem transition zone (which affects the results of foliage spraying), and the rather poor movement of the phenoxy compounds or their breakdown products into the lateral rhizomes (which affects the results of basal and stump spraying). Until these problems are solved, repeated spraying until the plant food reserves are exhausted remains our only choice.

DISCUSSION

Questions from the floor brought out the following points:

1. Number 2 fuel oil or kerosene commonly are used in the oil-water mixtures for foliage sprays.

2. A common dosage of phenoxy acids in ester form is 3 to 4 pounds of acid per 100 gallons of water.

3. In the East basal sprays have been less effective in November, December, and January than at other times.

4. In oil applications, use 2-percent acid, or 16 pounds of acid per 100 gallons of oil. Less may be satisfactory, but do not go below 1- to 1.5-percent acid.

5. Use basal sprays where resistant species make up a large percentage of the brush stand; otherwise foliage sprays can be used.

6. Phenoxy compounds are somewhat harmful to conifers; damage is less if spraying is delayed until late summer when conifer foliage has hardened-off. In Christmas tree plantations, brambles have been treated with 2,4,5-T amines in late August without serious damage to the conifers.

THE PLACE OF CHEMICAL CONTROLS IN FOREST MANAGEMENT

Paul O. Rudolf
Lake States Forest Experiment Station[1]

Forest trees almost always are subject to competition, from the time they sprout until they are harvested. Some competition is beneficial but too much decreases the vigor of the desirable trees and reduces stand productivity. Therefore, one of the most important jobs of a practicing forester is to control plant competition.

Such control may include (1) ground preparation to aid natural seeding or artificial regeneration, (2) liberation of young trees from overtopping vegetation, (3) removal of low-value trees interfering with the development of better trees, and (4) thinning overdense stands. These operations involve costs which often are not offset by returns for many years. To balance silvicultural desirability against economic feasibility, foresters must be constantly on the alert for improved practices. Consequently they have been greatly interested in the possibilities of chemical control of woody plants. Development during the past decade of such nonpoisonous, relatively inexpensive, and easily handled chemicals as the phenoxyacetic acids or hormone herbicides (2,4-D and 2,4,5-T) and ammonium sulfamate, and of improved methods of application, both from the ground and from the air, have greatly stimulated interest in chemical control of woody plants.

GROUND PREPARATION

Following logging and fires several million acres of land formerly in timber were reclaimed by brush in the Lake States. Much of this land, to be restored to valuable forest growth in reasonable time, must be artificially reforested. Where the terrain is not too rough, the soil not too rocky, and solid stumps or down logs not too numerous, the ground can be prepared for planting or seeding at moderate cost with heavy plows, Athens-type disks, root rakes, or perhaps controlled burning. Unfortunately, however, the brush often sprouts vigorously after such treatment and the expense of release must be added to that of planting or seeding if the restocking is to succeed.

Chemical methods of ground preparation hold forth considerable promise both on areas suitable for mechanical site preparation and where physical obstacles make mechanical methods too difficult. The right chemicals properly applied not only kill the tops of many brush species but also prevent or retard sprouting. Dollar for dollar they may, therefore,

[1] Maintained by the U.S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota.

be more effective than mechanical methods or fire. Of course, control methods for some shrubs have not yet been found. For example, sweet-fern, which occupies considerable areas on sandy soils, has proved quite resistant to hormone sprays.

An example of chemical site preparation on a relatively large scale is an area near Bena, Minnesota on the Chippewa National Forest. Fairly dense brush (willow, hazel) on a pine site was given a foliage spray of brush killer (mixture of 2,4-D and 2,4,5-T) in the summer of 1951. The top kill was excellent. In the spring of 1952 the area was planted to pine at a very reasonable cost, using a planting machine preceded by a pusher plow.

Aerial application of chemical herbicides has also been tested in northern Minnesota. In August 1951, brush killer in diesel oil was applied from a plane to 15 acres of swamp covered with alder, willow, and dogwood brush. Initial kill was excellent, but there has been resprouting. It is not yet known if sprouting will be heavy enough to require release of black spruce planted on the area.

In some parts of the west, brush killed by aerial spraying has been burned over to facilitate hand planting. Such a practice may have only limited application in the Lake States where planting machines can be used in conjunction with pusher plows. The dead brush may, in fact, have some value in reducing surface soil temperatures and slowing down invasion of other plants.

Chemical brush control should be followed by planting or seeding without long delay. Normally, grasses and herbaceous growth come in after the brush is killed. This new growth may offer serious competition to small seedlings. Those which are well established, however, have a fairly good chance of staying ahead of new growth.

RELEASE FROM OVERTOPPING VEGETATION

Tree seedlings often become overtopped by brush or other trees of less value. Some millions of acres are in this condition in the Lake States. If not released from competition, the overtopped trees lose vigor and often die. Release by hand methods is relatively expensive and frequently must be repeated one or more times before the desirable trees can keep ahead of their competitors. A number of tests have shown that chemical herbicides have promise for release work.

Low Release

When coniferous seedlings are overtopped by brush, chemical control methods similar to those used in ground preparation are useful. Foliage sprays of hormone herbicides or ammonium sulfamate applied in midsummer have given fairly good control of a number of species. As an illustration, an area on the Chippewa National Forest was seeded to jack pine

and partially planted with red pine after a fire. The catch was good, but a rather dense growth of bigtooth aspen also came in and quickly overtopped the pines. A part of the area was given a foliage spray of brush killer in June and a good kill of aspen resulted. Some of the jack pines sustained bud injury from the spray and about 15 percent of the red pines were killed, but the majority are coming along and should restock the area satisfactorily. In contrast, the aspen are growing vigorously on the untreated area, and few of the pines will come through unless they are released.

High Release

When desirable trees are overtopped by other trees somewhat different release methods are required. The trees most commonly competing with more desirable species in the Lake States are aspen, oaks, and red maple. Release usually is accomplished by cutting or girdling them.

Numerous tests in this region have indicated rather successful control of weed trees by applying chemical herbicides in notches cut at intervals around the stem, in frill girdles about the stem, on cut stumps, and as basal sprays around the lower two feet of the stem.

For example, scrub oak in central Wisconsin and Lower Michigan has been controlled satisfactorily, with little resprouting, by applying ammonium sulfamate in notches cut at 6-inch intervals about the stem. Red maple and aspen responded similarly to the treatment. Aspen, however, sprouted quite a little the second year after treatment; the other two species did much less sprouting.

In Lower Michigan, the initial costs of controlling the tops of scrub oak by applying 2,4,5-T to frill girdles on a 100-acre test were about one half those for regular axe girdling. In addition, sprouting was greatly reduced by the chemical method. The frill girdling treatment has been similarly successful with red maple and aspen.

Oak, red maple, and aspen have also been controlled by applying ammonium sulfamate to freshly cut stumps of 4-inch and smaller trees. Some sprouting accurred the second year, especially in aspen.

Basal sprays of 2,4,5-T in diesel oil have proved very effective in controlling individual scrub oak or red maple trees in Lower Michigan. Not only are the tops of the treated trees killed but sprouting also is retarded for about three years. Scrub aspens treated with basal sprays between the time of full leaf development and the dormant season have not suckered three years later. This is the first measure found for controlling aspen without prolific sprouting and suckering. The labor cost of the actual basal spray work is much less than that of axe girdling. However, the delay time in refilling sprayers and added supervision bring the cost above that of conventional axe release. Furthermore, the cost of the chemical in the relatively

heavy applications makes it uneconomic at present to use basal spray on trees above about 6 inches d.b.h. on sizable operations.

THINNING DENSE YOUNG STANDS

Natural stands sometimes start out at such a dense stocking that individual tree growth is greatly impaired if they are not thinned at an early age. Foresters have an understandable reluctance to make non-commercial thinnings at present labor costs.

In Canada, chemical sprays have been tested successfully in thinning dense young lodgepole pine stands. Normally, sprouting is not an important consideration in thinning, so the chemical method will be useful only if it is cheaper than alternative methods. Although chemical thinning methods have not been tried in the Lake States, it is probable that they could be cheaper than conventional cutting in dense young stands of seedling size. However, it seems even more likely that some mechanical methods such as power saws might prove even more economical.

CHEMICAL CONTROL HAS A PLACE

Chemical control of woody plants has been tested for several years in the Lake States and recently has been used on a pilot-plant scale in forest management work. Some of the over-enthusiastic early reports have not been borne out. Chemical control is no magic method. It has limitations as well as advantages. However, evidence does indicate that chemical control can be a useful tool to add to those previously at the disposal of forest managers.

To prepare brushy sites for natural or artificial regeneration, chemical methods have some advantages over mechanical methods and fire. On susceptible species the chemicals largely overcome the troublesome resprouting which follows other methods. Chemicals can be applied from aircraft so that relatively large areas can be covered quickly and poorly accessible areas can be treated easily. In many cases combinations of mechanical and chemical methods may prove most effective. The major disadvantage is that many brushy species are not yet subject to satisfactory chemical control.

Under certain conditions chemical release work has been done at a considerable saving in cost over conventional cutting and girdling. Here, too, there is a possibility of treating fairly extensive areas from aircraft. Helicopters, used for this purpose in the West, might prove useful where frequent skips or breaks in area treated were necessary. In many cases combinations of the old and new methods may prove best. For example, merchantable weed trees could be harvested and the stumps treated to reduce sprouting.

Perhaps the principal disadvantage of chemical methods in release work is the danger of injury to the trees being released. Care must be used in applying the chemicals. Even then some losses may result. In Lower Michigan, for example, some red pines died in a stand where aspen had been treated with ammonium sulfamate in notches. The pines which died had root contact with treated aspens and presumably absorbed some chemical through this channel. Some similar injury was reported for white pine in the East.

For some purposes elimination of woody plants is stressed, but for forest management purposes, this may be unnecessary if not undesirable. In many cases it may be preferable to have the controlled plants sprout at reduced vigor, rather than to have them eradicated. Such low-vigor sprouts will not compete seriously with the desirable trees. Yet they may furnish some browse for wildlife, retard invasion of other plants, and add their foliage to the litter and help produce more healthful soil conditions. Even where plant elimination is desired, it is probable that many of the plants weakened by chemical applications will gradually succumb to insect or disease attacks which vigorous plants normally could withstand.

FUTURE PROGRESS

It seems clearly evident that chemical control merits a place in forest management. However, a continuous process of experiments followed by pilot-plant tests of promising leads is needed to guide large-scale application of chemical control methods.

As new chemicals and new formulations of older chemicals become available they should be tested thoroughly, especially on species which have been resistant to chemical control. More effective equipment and methods of application should be sought; those now available were not developed for forestry purposes. There must be further search not only for the minimum effective rates of chemical required but also for the minimum volume of diluent needed for effective control. For both ground and air applications the pay load must cover the maximum possible area to make chemical control most useful to the forest manager. Last, but not least, much more knowledge is needed on the physiology and ecology of woody weeds to delineate both the possible effectiveness and limitations of various chemical herbicides.

Backed by necessary research and demonstration chemical herbicides can retain, and even expand, the place they now warrant in forest management. Along with the axe, the plow or disk, and fire, they can help the forester in his everlasting job of controlling plant competition at reasonable cost.

DISCUSSION

A question of costs of aerial spraying with hormone herbicides brought out that a test in Lower Michigan was done at a cost of $5 per acre, about half of the cost being for chemicals.

ECOLOGY OF SOME WOODY WEEDS

Henry L. Hansen
School of Forestry, University of Minnesota

"The study of organisms in relationship to their environment" is a definition frequently given to the area of scientific thought and experimentation included in the term "ecology." Frequently two separate aspects of ecological relationships are also recognized. The term "autecology" is applied to the study of the interrelations between the individual and the factors of its environment, and the term "synecology" applies to the structure, development and other aspects of communities.

These two facets of ecological study are mentioned because both have a place in the woody weed research projects which have been carried on for the past six years by the School of Forestry. This research was undertaken to learn more about the life history and processes of the woody plants commonly referred to as "brush" and to understand better the role played by brush in the forest community. Attention has been directed to such specific questions as:

1. What are the light requirements of the various brush species, and can the light factor be used as a means of control?

2. How does the brush regenerate?

3. How does brush invade forest stands?

4. What is the rate at which brush colonies develop following invasion?

5. Is brush only a temporary component of forest stands and, if so, what role does it play in the life history of the stand?

It has been felt that this fundamental ecological approach would give information of value in the silvicultural management of the forest as well as knowledge that might be of considerable value in developing specific brush control techniques. In addition, it was felt that graduate students working on these projects would be given a good fundamental training in the biology of forest vegetation that would be useful to them in their later professional work. The School of Forestry, having several forest ecologists on its faculty and with close contact and cooperation with ecologists in the Department of Botany is well staffed to give major emphasis to these studies.

In recent years the following specific studies have been or are currently being conducted:

1. "The Ecology of Wolfberry (Symphoricarpos occidentalis) in Minnesota," by John Pelton. 1951. A Ph.D thesis; results published in Ecological Monographs for January 1953.

2. "Some Ecological Aspects of Prickly Ash with Respect to Possibilities for its Control by the Use of Chemicals," by J. Donald Meyer. March 1951. A Master of Forestry Thesis.

3. "The Origin and Early Growth of Quaking Aspen Root Suckers," by Dixon Sandberg. April 1951. A research problem report.

4. "An Ecological Study of Beaked Hazel in the Cloquet Experimental Forest, Minnesota," by Wm. Wen Yue Hsiung. June 1951. A Ph.D thesis.

5. A study of the ecology of alder currently under way by Bruce Brown, graduate student and holder of the Kimberly-Clark Fellowship.

6. Studies of the interrelations of brush, deer, light and natural regeneration of conifers begun in 1947 at the Itasca State Park Forestry and Biological Station.

7. Studies of the processes of brush invasion and colonization begun in 1952.

The results of all these studies can scarcely be considered in this brief presentation. However, in order to illustrate the significance of some of the results, reference is made to a number of conclusions arrived at concerning hazel (*Corylus cornuta*).

1. This species must invade initially by means of an animal vector. Squirrels burying the nuts and failing to dig them up are largely responsible for this initial invasion.

2. Growth of the seedlings is extremely slow. Seedlings 10 to 15 years of age average only about 2 feet tall.

3. Seedlings do not flower and produce nuts.

4. At an average age of 7 years, dormant buds in the axils of the original cotyledons develop into either aerial or underground stems. This is the beginning of colonization and is encouraged by death (cutting back, fire, etc.) of the aerial stem of the seedling.

5. The process of colonization by vegetative regeneration continues at an accelerating rate. Regeneration can be by sprouts either from the base of aerial stems, from underground stems, or from layered stems.

6. The rate of colonization is slow at first with an average of only 2 to 4 aerial stems in a 20-year-old colony. At 30 years there is an average of 14-16 live stems and at 38 years, when the process has greatly accelerated, there is an average of 24 - 26 live stems.

7. Light is the most important environmental factor influencing the density of hazel colonies. Low light intensities such as prevail in spruce-fir stands permit only weakly developed colonies while full sunlight induces vegetative multiplication.

Studies are currently under way on alder. While final analysis has not yet been made of data collected, several things seem apparent. This species does not have the vigorous development of underground stems as does the hazel. Those present are only a foot or two long. Regeneration is largely by basal sprouts and layers. In addition, the seed must have a wet seedbed in order to germinate. These characteristics explain the relative ease of controlling alder by chemical sprays and also the reason this species does not generally invade upland areas.

In studies involving the community relations of brush and natural regeneration of pine seedlings, it has been demonstrated that chemical control of the brush can in some cases favorably affect the abundance of pine seedlings. On one of the oldest (1948) sets of spray plots, the number of pine seedlings is 240 percent greater than on the comparable check plots after five growing seasons. On these sprayed plots the hazel brush regrowth is still not competing appreciably with the young pine seedlings.

It is felt that investigations of the nature cited are necessary to a proper understanding of what the brush problems in forestry actually are and also give direction to the development of control techniques.

DISCUSSION

A question brought out the following point: although disking or other ground scarification usually results in increased aspen suckering, results of such treatment after chemical control of aspen would depend on the extent to which the aspen roots had been killed by the chemicals.

RESPONSIBILITY OF REGULATORY PERSONNEL IN THE CONTROL OF BRUSH

Sig. Bjerken
Minnesota Department of Agriculture, Dairy and Food

Control of brush is important and I would like to discuss this subject from the regulatory aspects. However, before doing so I would like to make a few comments on the State of Minnesota in general. The area of Minnesota is approximately 51 million acres, which includes about 14 million acres in grain crops, about 6 million acres in grasses and pasture, and some 15 million acres of tax-exempt State and Federal lands. In addition, there are approximately 116,376 miles of roads occupying about 1 million acres, or 2 percent of the State area. All of these lands are subject to weed infestations and are becoming infested, especially road right-of-ways and pastures.

Minnesota is divided into 1,846 townships and 976 villages. These townships and villages are governed by township boards and village councils elected by the people of their respective township or village. These boards and councils have many responsibilities, one of which is to provide roads for the people.

In order that the roads may be kept open at all times for the transportation of crops and livestock to market, for the regular movement of school buses, and for general travel, it is important that brush and weeds be removed from the road right-of-ways, which in most cases is four rods wide. Such removal is important in the winter so that brush will not interfere with equipment to remove the snow from the roadbed. It is equally important in the summertime that brush not be allowed to shade the roadbed and delay its drying following rains. With brush control, grasses will gradually replace brush and weeds and will have a tendency to encourage farmers in the future to mow the right-of-ways where brush and weeds now exist.

Upon failure of town boards to keep roads passable, complaints may be filed with the county board by the people affected, and if the findings show neglect the county board may hire the work done and charge all expenses to the taxpayers of the township. Therefore, it is important to the township boards that they have chemicals today to eliminate the brush without sterilizing the soil to the extent that grass will not grow in its place. Furthermore, these chemicals should be as nearly nonvolatile as possible in order that crops not be damaged adjacent to the right-of-ways. Then, too, we must not overlook the fact that over 90 percent of our farms are electrified and efficient service must be rendered in the upkeep of these lines. This can be done only through the clean-up of road right-of-ways adjacent to these public utility lines.

In closing I wish to emphasize again that town boards are required by law to eliminate any menace, including brush or weeds, on their road right-of-ways as well as on other property in the township. In doing so, not only do they keep the roads open for the public but they also help eliminate the weeds on other areas. Proper brush control along road right-of-ways helps preserve wild game, in our opinion, because the animals tend to stay out of the roads more with reduction in roadside cover. This can be important from a conservation standpoint.

DISCUSSION

Questions brought out the following points:

1. Most common damage suits result from spray drift on to agricultural crops.

2. No claims for injury to livestock, game, or humans from brush or weed control spraying have been substantiated.

3. On county roads the entire right-of-way (usually 2 rods wide) is sprayed.

4. To avoid unsightly appearance, brush along roads is cut first and then sprayed.

5. Care must be exercised in killing brush on steep cuts or fills to avoid erosion.

MOVIE ON WOODY PLANT CONTROL

A movie in color, furnished by E. I. duPont de Nemours and Company, showed before and after views of several right-of-way sprayings in the Northeastern States. Depicted were good kills of the dense brush resulting from ammonium sulfamate applied as a foliage spray. J. E. Prendergast arranged for the movie.

FOLIAGE SPRAYING IN CHEMICAL BRUSH CONTROL

Eugene I. Roe
Lake States Forest Experiment Station

INTRODUCTION

Prior to World War II, the usual methods of getting rid of undesirable woody plants were by means of cutting or by poisoning with sodium arsenite or other chemicals. This was laborious and expensive in the first case, and the second method had the disadvantage of being a serious hazard to livestock and wildlife. During the war, however, there came into use three new non-poisonous chemical herbicides which have revolutionized the whole field of brush control. These are ammonium sulfamate, commonly known as ammate, and two compounds similar to plant growth hormones, 2,4-D and 2,4,5-T. These chemicals have proved so effective that their use has almost supplanted the older methods of brush control.

Ammate is non-selective, killing practically all species of plants, while the "hormone herbicides" are generally effective only on the dicotyledonous plants, the group to which our common brush species and weed trees belong. Monocots, such as grasses, are not usually killed unless in juvenile stages. All three of these chemicals are readily absorbed through the leaves or stems of plants and are then translocated. As they spread through the plant tissues, at least the "hormone herbicides" seem to so stimulate the plant that it outgrows its food supply. Because of their ability to be absorbed through the leaves, these three herbicides

were first applied as foliage sprays during the growing season. As time has passed, it has developed that they can also be used effectively at other times of the year and applied to other parts of plants. This discussion, however, will be confined to foliage spraying.

FORMS OF CHEMICALS USED IN FOLIAGE SPRAYING

Since the salts and amines of 2,4-D had given good results with the common agricultural weeds, they were the first forms of this chemical to be used on woody plants. Ammate was also given a thorough trial. The latter, however, proved rather costly due to the large amounts which were needed and had the further disadvantages of being non-selective (that is, killing desirable species as well as undesirable ones) and corrosive to equipment. Because of these drawbacks, ammate is not used widely in foliage spraying in forest management at the present time. It is, nevertheless, a valuable chemical herbicide when used as an accessory to girdling and frilling and in the treatment of stumps to prevent sprouting. It is also used to considerable extent as a foliage spray in right-of-way spraying where a complete kill may be more desirable than is on the average brush control job.

Various esters of 2,4-D proved more effective on woody plants and have largely supplanted the salts and amines in the foliage spraying of brush. Esters are marketed in the form of oil solutions, which are readily mixable with water, the usual acid equivalent being from 3.3 to 4.0 pounds per gallon. The most common esters of 2,4-D (and also of 2,4,5-T) formerly used -- methyl, ethyl, isopropyl, and butyl -- have one disadvantage which may limit their use in agricultural areas. Especially sensitive plants may be killed by their fumes even though such plants actually may not be touched by droplets of the spray solution. This objection, which is probably of little importance under most wildland conditions, has recently been overcome in part by the development of new, low-volatile esters of both acids which vaporize much less readily. Among these are the propylene glycol butyl ether esters, the butoxy ethanol ester, and others. There is some indication that these new products are even more effective in killing action than the more volatile esters formerly used.

The closely related chemical, 2,4,5-T is toxic to certain woody plants on which foliage sprays of 2,4-D are relatively ineffective. Among these are: raspberry, blackberry, poison-ivy, and maples. 2,4,5-T also kills many of the same species as 2,4-D, but it is not recommended in such instances because its esters cost about twice as much as do those of 2,4-D. Areas containing both shrubs easily killed by 2,4-D and others killed only by 2,4,5-T should be sprayed with a mixture of esters of the two acids. Since these esters are readily mixable, the user can easily prepare his own mixture to fit the job at hand or he can use one of the so-called "brush killer" products put on the market by the various chemical manufacturers.

OTHER CHEMICALS

Dinitro weed killers also have been used on a limited scale in foliage spraying. These are selective herbicides when used in weak solution, but they act non-selectively in strong solution. Although the dinitros tend to kill leaves very rapidly, their action appears to be less lasting than that of the hormone herbicide for they are followed by considerable resprouting. Moreover, they are poisonous, they leave a permanent stain on clothing and skin, and are inflammable under certain conditions. They would thus appear to be of limited value in foliage spraying.

Another chemical which may have possibilities in this field is the compound known as MCP or 2-methyl-4-chlorophenoxyacetic acid. This is a relatively new product which is sometimes known as the "English 2,4-D" for it is quite similiar to 2,4-D in its chemical make-up. MCP has proven more effective than 2,4,5-T on some species and less effective on others. It would seem to deserve more trial especially on some of the species which are resistant to both 2,4-D and 2,4,5-T.

TIME, METHODS, AND RATE OF APPLICATION OF FOLIAGE SPRAYS

Time of Application

The time of application is important in foliage spraying. Although experiments with hazel in Minnesota indicate good initial kill from single applications of 2,4-D made at regular intervals from mid-June to late August, resprouting during the second year tended to be heavier and the sprouts larger and more vigorous on plots sprayed during the beginning and the end of the season than on those sprayed during July. Day, in Michigan, also found July spraying to be more effective than earlier or later spraying with several species. Spraying when the leaves are in full development and thus able to manufacture and translocate food would therefore seem best in most cases. Another factor which tends to favor mid-summer spraying is that all plant activity is at a high level then because of high temperatures which prevail.

Methods of Application

The method used to apply foliage sprays will depend on the size of the area to be treated and the height and density of brush on the area. Small, scattered tracts of low brush often can be sprayed most economically with hand sprayers. For such work, 5-gallon backpack fire pumps frequently are used. However, knapsack sprayers of the same size which build up pressure by means of a pump operated with the right hand and which are equipped with a trigger release valve allow for much better direction of the spray. If backpack fire pumps are used, they should be equipped with finer nozzles than those used for fire fighting.

Larger tracts of medium-sized brush can be sprayed with power sprayers mounted on "cat wagons" or trucks, depending on the terrain to be covered. Tall dense brush can also be so sprayed, but for such areas aerial spraying would seem preferable. Helicopters are coming into use in aerial spraying and may prove feasible for the spraying of areas too small for treatment by conventional planes.

Rates of Application

When foliage spraying was in its infancy, it was believed that the leaves should be soaked to the point of runoff. Such heavy application naturally required large amounts of spray solution -- 100 to 300 gallons per acre -- of which a sizable proportion dripped to the ground and was wasted. In order to keep costs low, weak solutions had to be used. As time has passed, it has become evident that as good or better results can be obtained by using finer nozzles to apply much smaller volumes of stronger solutions of the herbicides. This, of course, means more economical spraying costs. In the case of the hazel, probably the most troublesome brush we have to deal with in the Lake States, excellent kills are now being obtained from 20 to 50 gallons per acre whereas a few years ago volumes in the neighborhood of 200 gallons were considered necessary. With aerial spraying, one to four gallons of solution give adequate coverage of the foliage.

At Craigville, Minnesota, in a cooperative spraying study of lowland brush being carried on by the Minnesota Forest Service, the Minnesota and Ontario Paper Company, the Dow Chemical Company, the Minnesota Airplane Sprayers Association, and the Lake States Forest Experiment Station, a 50-50 mixture of the low-volatile esters of 2,4-D and 2,4,5-T were applied at the rate of 1.14 and 3.26 gallons of solution per acre. The initial kill, excellent on both areas, was somewhat better on the heavier spraying, but it definitely was not worth the almost threefold higher cost.

As for the amount of herbicide needed for good kill, the general feeling at present is to apply at least one pound of pure acid per acre on species which are readily killed (usually a mixture of 2,4-D and 2,4,5-T depending on the kinds of brush represented in the stand) and larger amounts for those which are more resistant to the herbicides. Translating this into terms of herbicide materials, it would require at least one quart per acre of an ester product with an acid equivalent of four pounds per gallon and more of one with a lower acid content.

In foliage spraying done from the ground, water is the preferred diluent. Kerosene or diesel oil is sometimes used but add unnecessary expense. In spraying from the air, however, oil or 1:3 oil-water emulsions are preferable.

WHEN FOLIAGE SPRAYING IS RECOMMENDED

Foliage spraying is the recommended method of applying herbicides to brush less than six to eight feet high composed of species which are readily killed, such as hazel, alder and willows. On taller brush, unless it is possible to spray it by plane, and on resistant species, other methods of application such as dormant sprays are likely to be more effective. Complete kill of the root systems is seldom obtained from one spraying; several applications usually are needed to accomplish this. However, the severe setback given the brush by the initial job may be all that is needed to accomplish the desired end. If complete kill of woody plants is essential, then other methods of applying the hormone herbicides or possibly other chemical herbicides should likely be used.

DISCUSSION

Questions raised in discussion brought out these points:

1. Species readily controlled by foliage sprays of 2,4-D are speckled alder, willows, sumac, and American elder; by 2,4,5-T are quaking aspen, blackberry, chokecherry, pin cherry, black currant, swamp black currant, American elm, silver maple, poison-ivy, and willows. For greater detail see Lake States Forest Experiment Station Miscellaneous Report No. 15.

2. If sprays have been on the foliage long enough to dry well, rains will not destroy their effectiveness.

3. The hormone herbicides in ester form gain little or nothing in effectiveness through adding detergents.

SUMMARY OF INFORMAL DISCUSSION ON SPRAYING WOODY PLANTS IN THE DORMANT STAGE

L. W. Melander
Region V, Bureau of Entomology and Plant Quarantine, USDA

In any kind of a chemical control or eradication operation the objective is to kill as high a percentage of the problem plants as possible. Chemical herbicides have been applied not only to plants in leaf but also to those in the dormant stage. This discussion will be confined to information on killing dormant woody plants with chemicals. However, no attempt will be made to discuss the economic feasibility of any dormant spray operation, because it is up to those responsible for the operation to determine whether the cost of the project would be offset by the benefits derived therefrom. Also there will be no attempt to differentiate between the ultimate results in terms of "control" or "eradication." We interpret the term "control" to mean the killing of a sufficient percentage of problem plants to accomplish the results desired for a given situation, whereas "eradication" is the complete kill of all problem plants at a given location or within a certain area.

TYPES OF CHEMICALS USED FOR KILLING DORMANT WOODY PLANTS

In our ever enlarging chemical tool chest, we have two general groups of chemicals, (1) soil sterilants, and (2) chemicals absorbed directly by the plants such as hormone type herbicides, ammonium sulfamate, etc.

Soil Sterilants

Soil sterilants, used for many years in killing dormant woody shrubs and trees, are applied to the soil at the base of the plant for ready absorption by the roots. These chemicals must be applied in quantities sufficient to effect a kill, or the effort will have been wasted. The following chemicals have been used as soil sterilants:

1. Common salt (sodium chloride) is effective as a killer of plants but large amounts usually are required to kill a shrub or tree.

2. Kerosene, distillate, and similar oils have been used to some extent, but they also must be applied in large amounts.

3. Sodium chlorate is an effective herbicide and is supposed to be about 10 times as toxic as common salt. In forests, it may constitute a fire hazard.

4. Sodium arsenite is a good killer of woody plants but is dangerous to use because of its poisonous qualities. Cattle that get a taste for it appear to go crazy and eat everything with arsenic on it, including soil, until they die.

5. Ammonium sulfamate is a good soil sterilant, which may also be used as a foliage spray.

6. Borax formulations also are useful for killing different types of woody plants.

7. CMU, a urea derivative, put out in recent years by the duPont Company, is a new soil sterilant which is showing unusual ability to kill trees of almost any species.

Hormone-Type Herbicides for Killing Dormant Plants

In recent years, 2,4-D and 2,4,5-T formulations have proved effective for killing dormant trees and shrubs. However, from a seasonal spray standpoint, it is necessary to note that these relatively new herbicides have forced us to change our concepts of when dormancy starts and when it ends. In spraying woody plants on a year-round basis, the time to switch from one type of seasonal spray to the other must be determined fairly accurately, but it is difficult to determine when to discontinue foliage spraying and to start dormant spraying. It has been found that dormant spraying should be started before the leaves fall, so there is

no clear-cut point where foliage spraying should be discontinued. When all evidences point toward the fact that the plants have ceased growth and the leaves and stems seem to have "hardened-off," dormant spraying should start. Since the time of this change varies with the season, there is a danger that field spraying crews in some years will be tempted to stretch the foliage spraying season. This may result in a poor kill.

When to discontinue dormant spraying and start foliage spray operations is more clear cut. When woody plants are coming out of dormancy, the translocation stream is predominantly upward. To effect a kill, herbicides applied as foliage sprays must depend upon being absorbed and translocated downward to the roots. This cannot take place effectively until the translocation stream moves downward. It appears that this does not start until food manufactured through the photosynthetic process is translocated downward toward the roots. This point in the seasonal growth of a woody plant seems to be when the leaves are fully developed and new shoots are starting. Therefore, dormant spraying should be continued until this stage of seasonal growth is reached. This probably explains why foliage sprays applied too early in the growing season often result in a poor kill of woody plants.

Kinds of Hormone-Type Herbicides

There are three hormone-type herbicides on the market, 2,4-D, 2,4,5-T and MCP. These are not sold in their acid form but are formulated and put on the market as salts or esters. There is a possibility that other types such as parachlorophenoxyacetic acid and others also may be put on the market.

The most commonly formulated salts are sodium and amine types. For selective killing of weeds in field crops, amine salt formulations seem to be the most popular. However, for dormant woody plants the amines are not as effective killers as esters and are not generally recommended for that purpose.

Esters of hormone-type chemicals have been found to be the most effective killers of dormant woody plants. They are formulated by combining acids of hormone-type herbicides with alcohols. Theoretically, there may be as many esters of these herbicides as there are kinds of alcohols. However, for our purposes, there are two general types of esters: high volatile, and low volatile.

It is obvious that the low volatile esters are safer to use where nearby crops may be injured by drifting vapors. Regardless of the fact that there is less danger of volatility doing damage during the dormant season, there still is a possibility of some damage even with winter spraying of shrubs and trees. More research is necessary to determine the danger of drift and volatility of hormone-type herbicides when applied in the dormant season. In view of these potential dangers it is recommended that low volatile esters with high herbicidal effectiveness be used.

The selective qualities of 2,4-D and 2,4,5-T which make it possible to kill some dormant plants and not others have resulted in the manufacture and sale of combinations of esters of these two chemicals for general brush killing. Theoretically, 2,4,5-T is supposed to kill what 2,4-D will not. Of course, there are shrubs and trees not killed by either herbicide. Here is where esters of MCP and possibly other hormone-type herbicides may prove of value when added to brush killer combinations. They may kill dormant shrubs and trees not killed by esters of 2,4-D and 2,4,5-T, resulting in the killing of a much greater variety of undesirable woody plants.

DILUENTS USED FOR SPRAYING ESTER FORMULATIONS ON DORMANT PLANTS

Common commercial oils such as kerosene, distillate, and diesel oil are generally used as diluents of ester formulations of hormone-type herbicides used for spraying dormant shrubs and trees. The lighter oils are especially efficient for use in cold weather. To reduce costs of spray mixtures used for killing dormant woody plants, water has been tried as a substitute for part of the oil. Some hopeful results have been obtained by some workers and emulsions may have possibilities during mild weather.

ADJUVANTS OR ADDITIVES TO INCREASE KILL

Penetrants such as pentachlorophenol, turpentine, etc. have been known to step up toxicity of esters in some cases, but further testing should be done before general recommendations can be made. We also should not rule out the possibilities of chemicals which in themselves may not have herbicidal value, but may have a synergistic effect when used with herbicides.

CONCENTRATIONS OF OIL SOLUTIONS FOR DORMANT SPRAYS

After several years of spraying dormant native barberry bushes, we have found that the minimum concentration that is effective on the dormant stage is somewhere between 7 and 10.5 pounds AHG, or 1 and 1.5 percent respectively. This also has been found to apply to concentrations used on dormant trees and shrubs sprayed along right-of-ways. Therefore, it is our opinion that an effective dormant spray concentration should be an oil solution containing not less than 14 pounds acid equivalent in 100 gallons of spray mixture. This is expressed as 14 pounds AHG. Most research workers prefer a minimum of 16 pounds AHG.

METHODS OF SPRAYING OR TREATING DORMANT SHRUBS OR TREES

Within the last two years it has been quite definitely established that for most trees and shrubs the most vulnerable spot for treating with hormone-type chemicals is the ground line. This is true of standing trees as well as live stumps. However, this does not eliminate the effectiveness of treating cut surfaces of stumps which in addition should be sprayed at the ground line. This ground-line treatment principle also applies to shrubs which should be thoroughly sprayed on the ground area which they occupy. For low growing shrubs, the whole bush should be covered.

Many shrubs and some trees reproduce by underground stems. As a result these bushes grow in patches, sometimes several acres in extent. In spraying native barberry bushes which have this habit of growth, we have been able to obtain almost 100-percent kill by thoroughly spraying the bushes, with special emphasis on the ground line, as well as the surrounding soil for about four feet beyond the last shoot. There is no reason why this same method of treatment should not be successful on dormant plants of other shrubs with a similar growth habit. We, therefore, recommend that this technique also be tried on problem trees that develop from underground rhizomes.

SELECTIVE AND GENERAL COVERAGE SPRAYING

In view of the relatively large amount of hormone-type herbicides required to kill dormant woody plants and the fact that most of the lethal dosage should be concentrated at the ground line, aerial spraying of the dormant shrubs and trees does not appear feasible at the present time. On the other hand, highly sensitive, easily killed species may be an exception. Selective aerial spraying of dormant plants is very important and deserves attention from a research standpoint.

For dormant spray operations, reliance still has to be placed almost exclusively on ground equipment with which patches of shrubs and trees may be treated individually.

In conclusion, it should be pointed out that killing dormant shrubs and trees with hormone-type herbicides is a new development, and it is therefore obvious that as time goes on, extensive research and experimentation will develop improvement in herbicides and techniques for killing dormant woody plants.

Acknowledgment is made to Messrs. R. H. Beatty, Maurice Day, L. L. Coulter, and others who have given me their opinions concerning the several points that I have discussed.

DISCUSSION

Questions brought out the fact that current information on woody plant control can be obtained from the Research Reports of the North Central Weed Control Conference. The 1952 report can be obtained at $2.00 per copy from H. D. Woods, Provincial Department of Agriculture, Winnipeg, Manitoba.

TWO PRIMARY FACTORS INFLUENCING RESULTS IN THE CONTROL OF OAK DURING THE DORMANT PERIOD[1/]

L. L. Coulter
The Dow Chemical Company

In the course of the development of recommendations for dormant brush control it has been necessary to investigate a number of factors which might influence the results obtained. Of the many factors involved, the two which emerge as dominant points for consideration are spray volume and point of application.

VOLUME-CONCENTRATION TEST

In April 1951 a test was set up to determine the relationship of spray volume to concentration in the control of dormant white oak (*Quercus alba*) trees. Before undertaking the test a number of trees were sprayed with volumes which appeared to be light, medium and heavy, in order to establish a standard for volumes in the main test. The amount of spray per inch of circumference required to cover a tree from the ground up to a point 15 inches above the ground was determined. On the basis of this preliminary test arbitrary volumes of 3 ml., 7 ml., and 11 ml. per inch of circumference were selected as representative of light, medium and heavy volumes. When this had been established, 210 trees of uniform size (8 - 9 inches in circumference) were tagged and measured. These trees were treated with concentrations of 4, 8, 12, 16, 24, 32, and 40 lb. 2,4,5-T acid equivalent as the propylene glycol butyl ether ester per 100 gallons of spray in No. 2 fuel oil and each concentration was applied in the three volumes previously indicated. Ten trees were sprayed in each treatment. Thus the experiment consisted of 7 concentrations applied in 3 volumes to 10 trees per treatment or a total of 210 trees.

In September 1951, each tree was rated according to the response shown at that time (table 1). A rating of 1 indicated little or no response, while a rating of 5 indicated that the tree appeared to be completely dead. Ratings of 2, 3, and 4 indicated relative responses between those two points.

The importance of volume was clearly evident. For example, four pounds AHG* at a high or even moderate volume gave results considerably superior to a concentration of 40 pounds AHG applied in a low volume. This occurred even though approximately three times as much chemical per tree was used in the low volume-high concentration test as with the high volume-low concentration test. The amount of chemical is about 360 mg. per tree for the low concentration -- high volume test and 1200 mg. per tree where the low volume-high concentration was used.

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* Acid equivalent per 100 gallons of spray.

1/ Reprinted from "Proceedings Eighth Annual Meeting of the North Central Weed Control Conference" - December 11, 12, 13, 1951.

Table 1. -- The relative effect of various concentrations of 2,4,5-T ester applied in several volumes of oil to white oak trees*

Ml. of inch of circumference	Pounds of acid per 100 gallons of spray						
	4	8	12	16	24	32	40
3	1.5	2.0	2.1	2.2	2.2	2.5	2.8
7	3.2	4.1	3.5	4.9	4.9	4.6	4.9
11	4.3	4.5	4.9	5.0	5.0	5.0	5.0

* Each value represents a mean for 10 trees. Rating 1.0 indicating no effect and 5.0 appearing dead.

Since this experiment has been in progress for a relatively short period of time the writer does not wish to imply that these results are final. However, it is reasonable to assume on the basis of past experience that as far as the volume relationship is concerned the trend will continue to be the same.

The implications of this test may be important to research groups in the standardization of experiments and to the commercial applicator in obtaining good results. For instance, if two research workers treat oak trees with 2,4,5-T ester at a concentration of 16 pounds AHG, using volumes which appear to be similar but are actually quite different, the results may vary from slight effect (2.2 in table 1) to complete kill (5.0). These differences are invariably attributed to such tenuous factors as soil, temperature, etc., when in reality they probably are purely manifestations of the spray volume employed. In commercial use the importance of volume should be stressed to insure satisfactory control.

PLACEMENT STUDIES

Previous field tests where sprays were directed at different parts of the plant have been reported. These tests indicated the importance of applying the spray to the base of the plant. In order to obtain further evidence on this particular point and to learn more about the nature of herbicidal action during the dormant period a more refined test was initiated in April of 1951.

Clumps of oak sprouts, three years old, were hand painted at various points with No. 2 fuel oil containing 16 pounds acid equivalent of

2,4,5-T as the propylene glycol butyl ether ester per 100 gallons of mixture. The points of application included: (1) basal area from the ground up to a point 15 inches above the ground; (2) mid-section from a point 15 inches above the ground up to a point 30 inches above the ground; (3) terminal area from terminal bud down 15 inches; (4) top half from terminal bud down 30 inches; and (5) bottom half from ground up to a point 30 inches above the ground. Applications were made with a fine brush in such a manner that there was no appreciable amount of oil running below the lowest point of application. Downward movement could possibly occur later, of course, through one of several processes by which liquids move through or along the stem. Each treatment was repeated in 10 complete clumps, thus giving 50 clumps (2 to 10 stems per clump) in the entire test.

These treatments were checked for response in October 1951. In general the results may be summarized as follows:

1. Basal 15 inches: No plants showed leaves on original stems. These original stems are dead throughout their entire length with the exception of a few which show some live cambium in the area approximately midway from top to bottom. Most of these clumps had produced new sprouts from the old stump by the time observations were made.

2. Mid-section: This treatment in general killed the terminal area back as much as 20 inches. Where no terminal kill was evident the development of leaves was suppressed. Actual kill in the center area failed to develop although leaf development was suppressed and an occasional stem showed some proliferation.

3. Terminal: When the terminal 15 inches was treated some kill was obtained in the area treated and an average distance of 10 inches below the lowest portion of the treated area.

4. Top half: Applications over the entire top half of the plant killed stems in the terminal area but failed to kill the lower portion of the treated area which constituted the mid-section of the plant as in treatment 2.

5. Bottom half: When the plant was treated from the ground up to a point 30 inches above the ground essentially the same results were obtained as when the basal 15 inches was sprayed, i.e., complete kill of the aerial portion of the plant with sprouts from the old stump.

DISCUSSION OF FINDINGS

There are numerous references in the literature to the importance of spray volume. These tests seem to emphasize the fact that we are on sound ground with our recommendations that the spray material should be applied in such a manner that it is allowed to run down to the root crown.

in considerable quantity. Poor results with airplane applications during the dormant season are probably due to insufficient volume and to the fact that the small amount applied does not accumulate in the crown area. It is interesting to note that the best though not necessarily completely successful treatments generally show some kill of vegetation around the base of the treated plant. In a test where an area of mixed grasses and perennial weeds was sprayed with a mixture of 2,4,5-T (propylene and poly propylene glycol butyl ether ester) in a concentration of 16 lb. AHG in fuel oil, it was found that a minimum of 600 gallons per acre was the necessary volume required to give the same degree of kill as is often noted on vegetation at the base of sprayed trees. We may actually be using an even higher volume where our best brush control is obtained. The varied responses of trees to different volumes of a given concentration strongly suggest that we should consider the possibility of standardizing our volumes per plant for research work on sizable woody species.

The practical interpretation of the placement tests is to further our conviction that the basal area is the critical area of application. The fact that these painted basal treatments permitted new stump sprouts to develop (except treatments 2, 3, and 4 where top-kill was not complete) may reasonably be explained by the fact that these were essentially low volume tests which did not permit any runoff to the crown area.

From a theoretical point of view these tests are of interest because they point out something of the herbicidal action involved during the dormant season. They indicate that the lethal effects from dormant treatments move upward or at least appear above the point of application but do not move downward as extensively. Perhaps this movement downward is no further than the movement of the oil; hence the necessity of using high volumes which run freely down the stem and crown.

One other point of interest is the relative resistance of the central area of the stem. This area apparently can absorb the chemical and move it to the terminal area which is in turn killed without actually absorbing an acute dosage itself. This phenomenon of green central stems has been observed in high volume and aerial foliage sprays and has been explained in terms of coverage but this appears to be an example of actual physical contact without acute effect.

CHEMICAL FRILL GIRDLING FOR CONTROL OF UNDESIRABLE HARDWOOD TREES

J. L. Arend
Lake States Forest Experiment Station

A "frill girdle" is described as "a single line of overlapping downward axe cuts, leaving a frill into which toxic materials may be poured." If the toxic materials are not applied, the frill girdles usually will callous over sufficiently so that the woody plant to be controlled is not greatly affected.

HERBICIDES USED IN FRILL GIRDLES

Frill girdles have been used for many years as a means of injecting toxic chemicals into trees to be controlled. One of the most common methods used 25 or 30 years ago was a water solution of sodium arsenite poured into frill girdles. This method gave very effective control of several species when applied during the early growing season. However, the method was considerably less toxic to trees during the dormant season. Because sodium arsenite is quite toxic to animals, however, the method is not generally recommended for controlling undesired hardwoods. Other chemicals will do the same job with less toxic hazard to livestock, wildlife, and the men handling the material.

The herbicidal properties of ammonium sulfamate (more commonly called ammate) became established about 10 years ago. This herbicide is soluble in water and has been used rather extensively throughout the South. Ammate can be applied to trees as a water solution in frills or as dry crystals in cups cut at the base of the tree.

In general, ammate has proved more effective when used in crystalline form than in a water solution. Ammate does not mix well with oil. The principal objection to the method of applying dry ammate crystals to "notches or cups" at the base of the tree is cost. This particular control method costs approximately twice as much as regular axe girdling methods. The total labor costs for the ammate cupping method are about one-third more than notch girdling plus the additional cost of the chemical itself.

The frill method, using a water solution of ammate, is less costly than applying ammate crystals to "notches or cups" cut at the base of the tree for hardwood control. Four pounds of ammate crystals per gallon of water is the preferred concentration, although two pounds per gallon is often recommended. However, the frill method, using a water solution of ammate, has been found to be somewhat less effective in hardwood control than the dry crystalline form. Nevertheless, the frill method is more commonly used because of reduced costs.

A water solution of ammate can also be injected in the trees by means of the Cornell tool instead of in frills cut by the axe. Satisfactory control of oak has been reported using a Cornell tool filled with a concentrated (32.4 percent) solution of ammate. With this instrument, a continuous series of overlapping cuts are jabbed around the tree near the base. The main difficulty with this method is that the Cornell tool does not hold much solution; in fact, the tool is often emptied after 75 to 80 jabs. This difficulty can be overcome by the operator's back-packing a small tank which has a supply hose leading to the handle of the tool. Cost of application, using the Cornell tool, has generally been found to be less than cutting a frill with an axe and then pouring a water solution of ammate into the frill.

In the Southeast it was found that 8 pounds of 2,4,5-T ester acid equivalent mixed in 100 gallons of water when added to frills gave very good control of undesired hardwoods with absolutely no sprouting. A 2 percent by volume mixture of 2,4,5-T ester in water costs about the same as 2 pounds of ammate mixed in water. Since the ammate solution is corrosive to equipment and has been found to be slightly less effective than the 2,4,5-T water mixture, the latter was recommended for hardwood control.

Contrary to results in the Southeast, the water mixture of 2,4,5-T when added to frills cut in scrub oak in northern Lower Michigan often killed only about 50 percent of the treated trees at the end of 2 years. Furthermore, practically all of the affected trees sprouted the first year after treatment.

The Lower Michigan tests indicated that 4 pounds of 2,4,5-T ester acid equivalent per 100 gallons of diesel oil, when added to frill girdles, was very effective in controlling scrub oak, aspen, and red maple. This concentration is equivalent to a one percent mixture by volume for 2,4,5-T products containing 4 pounds of acid equivalent per gallon. Approximately a 100 percent top kill can be expected from this method and only about 50 percent of the trees develop weak sprouts.

COST OF FRILL GIRDLING

The labor costs for frill girdling are governed largely by the number and size of trees treated. To put them on a uniform basis it is helpful to report the cost per square foot of basal area of stems treated. A test in the Southeast, using 2,4,5-T in water 8 pounds AHG, gave an average cost of about 15 cents per square foot of basal area treated. Labor was figured at $1.20 per hour and herbicide at 30 cents per gallon.

A similar frill girdling cost test was made in northern Lower Michigan for which data are available. During a regular plantation release operation on the Lower Michigan national forests, the hardwood trees

4 inches at breast height and larger on approximately 55 acres, were frill girdled and a one percent mixture by volume of 2,4,5-T in oil was added to the cut frills. One gallon of this type herbicide (containing 4 pounds of 2,4,5-T ester acid equivalent per 100 gallons of diesel oil) costs about 30 cents[1]. The hardwoods in this stand were mainly oaks ranging from 1 to 24 inches in diameter. Only trees 4 inches d.b.h. and larger were frill girdled. Trees of this diameter range averaged 85 per acre and occupied about 28 square feet of basal area.

Item	Per acre
Labor (minus supervision) - 2.04 hours at $1.20	$ 2.45
Chemical - 1.23 gals. at 30 cents	.37
Total	$ 2.82

Total costs per acre were $2.82 for labor and chemical to treat trees occupying 28 square feet of basal area, or about 10 cents per square foot of basal area. One possible explanation for the slightly reduced costs in Lower Michigan as compared to the Southeast is that a shallower frill girdle can be used with the oil carrier herbicide and less herbicide is required for control compared to water carrier herbicides.

TECHNIQUES OF APPLICATION

The effectiveness and costs of the various methods of chemical frill girdling are influenced by the crew organization, equipment used, and techniques.

Crew Organization

In general, woods crews for chemical frill girdling, using an axe to cut the frills, should be in multiples of 4 men -- three axmen on the average to one man pouring the chemical herbicide into the cut frills. One woods foreman can supervise efficiently a crew of eight men (6 axmen and 2 men to handle the herbicide).

1/ 2,4,5-T ester containing 4 lbs. of acid equivalent per gallon costs about 15 dollars in one-gallon quantities. The price of grade No. 3 diesel oil is approximately 15 cents per gallon.

Axes

Any standard woods axe is a handy tool for cutting the frill girdles. Only relatively short swings, with a heavy axe, are needed to frill girdle. On limby trees the axman (by taking a shorter grip on his axe handle and reaching in among the branches) can make a cut sufficiently deep for a chemical frill girdle with a very short axe stroke. Because of the shorter axe strokes required to make the shallow incision necessary for a chemical frill, the axe work is less tiring and the accident hazard is reduced compared to regular axe release.

Equipment for applying the herbicide to frills

Non-corrosive containers are needed for ammate solutions. One gallon glass jugs have been used but they are not very practical on extensive operations because of breakage and the need for constant refilling. A good receptacle for handling ammate solutions remains to be developed.

Mixtures of 2,4,5-T in either oil or water are non-corrosive. However, oil usually deteriorates rubber hoses after constant exposure.

A 5-gallon backpack sprayer with a shut-off nozzle attached at the end of the discharge hose is very practical. A small amount of pressure in the can permits the application of the chemical herbicide to the frill much faster than with a gravity-fed can, which works well only when it is full. We also found that some axmen occasionally cut their frills quite high and it is difficult to pour the herbicide into high frills from a gravity-fed can. In fact, we found that one man with a pressure-type container is able to treat about twice as many trees in one day as a man using gravity-fed receptacles.

A red dye is often used with water carrier herbicides to determine which frills have been treated. With the oil carrier herbicide, dyes are also suggested. However, by allowing a little of the oil carrier herbicide to trickle over the sides of the frill, the oil mark is visible on the tree for several days after the treatment.

Other techniques

When either a water solution of ammate or a water mixture of 2,4,5-T is used, the frill girdle needs to be completely cut around the tree to a depth of about 1/2-inch or deeper. Also the frill must be filled with the herbicide, which requires going around the tree twice at average speed or once slowly.

With 2,4,5-T in oil, the frill girdle can be very shallow -- cut only through the bark to a depth of 1/4 to 1/2 inch. In fact, no special care is needed in making a continuous cut around the tree. The frill

girdle can be hacked around the tree in a rough fashion as is often done by unskilled woods labor. The oil mixture, if applied freely to the frill girdle, will penetrate most narrow uncut portions of the bark sufficiently to kill the tree.

RECOMMENDED FRILL METHOD FOR THE LAKE STATES

The 2,4,5-T ester mixture in diesel oil seems to be a fairly satisfactory method for controlling most undesirable hardwoods on extensive forest management operations in the Lake States region. It is much more convenient to handle in the winter time than water carrier herbicides. The method has proved very effective on scrub oaks of all species, cherry, aspen, and red maple. The treatment is somewhat less effective on sugar maple. Possibly a deeper frill and an extra dose of the herbicide will give a good top kill for sugar maple also.

When this method is used, trees too small for frill girdles can be cut close to the ground, and the tops of freshly cut stumps thoroughly wetted with the same 2,4,5-T oil mixture that is poured into the frill girdles.

According to present information, chemical frill girdling with a 2,4,5-T ester mixture in oil appears to be the least expensive method for hardwood control in most forest plantations in northern Lower Michigan.

DISCUSSION

Points brought out by the discussion were as follows:

1. Height of frills does not affect costs very much, but low frills give somewhat better kills than higher ones.

2. By diluting the chemicals 100 to 1, resprouting has been reduced to 50 percent of that obtained with ordinary girdling, and the vigor of these sprouts is also very low. Increasing the concentration of chemicals might give more complete control, but the control obtained with present dosages is adequate for most forestry purposes.

POWER SPRAYERS FOR CHEMICAL HERBICIDES

J. McCartney
Northern Chemical Service

Power equipment for the application of chemicals, whether to field crops, fruit trees, powerline brush, or the forest, can be divided into three types: (1) power sprayers, (2) power dusters, and (3) mist blowers. The basic differences between these types is the material used to dilute the chemical being applied. Power sprayers use a liquid, usually water

or oil; dusters use talcum powder or a very fine clay called "pyrophyllite"; and the mist blowers use air.

For the average brush spraying we would expect to use about 150 gallons of water per acre using a power sprayer, about 175 pounds of dust with a duster, or about 86,400 cubic feet of air with a mist blower.

In actual practice at present little or no brush is being dusted; most of it is being sprayed with high pressure sprayers. There are, however, a number of operators using mist blowers for applying 2,4-D and 2,4,5-T and other brush control chemicals. The same type of blower in a smaller size has been used experimentally at the Cloquet Forest Experiment Station.

Discussion of power sprayers can be limited to the major types manufactured by the John Bean Division of Food Machinery Corporation; the Hardy Corporation; and the A. B. Farquahar Division of the Oliver Corporation. A number of other sprayers are offered for sale, but if you were to make a check in Door County Wisconsin, in the area near Gays Mills, Wisconsin, or near La Crescent, Minnesota, where the fruit growers have been spraying apple and cherry trees for 40 years or more you would find few sprayers of other makes.

The only part of a sprayer which really costs money, in comparing original purchase price, is the pump. Tanks, hose, engines, wheels, and tires, etc. are all standard and readily comparable. There are several specifications which should be incorporated in any purchase order, as listed below:

1. High pressure neoprene hose (such as Gates 17B).
2. Mechanical agitation in the tank.
3. Electric starting.
4. Air cooling of engine, or a copper radiator on water cooled engines.
5. Chemical-resistant painting inside and outside on the entire spray rig. The only really effective paint we have found is Herusite baked-on finish.
6. Copper or stainless steel filter screens.

These specifications may seem to be rather unusual, but I have developed them from our experience. Only the best type of neoprene high pressure oil resistant hose should be used since you may be using ammate, 2,4-D emulsion, 2,4,5-T in oil, CMU, Sodium TCA, pentachlorophenol, or probably some new material. You need mechanical agitation for CMU, sodium TCA, and ammate, and it is beneficial for any spraying.

Ammate will ruin an inferior radiator and will rust up everything in sight unless a paint such as Herusite is used. Also it is well to let your spray rig get well covered with oil and grease as an added protection against ammate; filter screens will rust out unless they are copper or stainless steel. In our equipment we use mostly bronze pipe fittings and valves for the same reasons.

NO IDEAL SPRAY RIG

In trying to determine what type of spraying equipment would be the best for use in forest management, we find that there are a number of different problems which cannot be handled as economically one way as another. Spraying fire lanes, logging roads, trails, etc., can best be done with a high pressure spray rig. Girdling of undesirable trees and their treatment with chemicals can best be done with knapsack sprayers, or with dry ammate crystals carried in a can. Overall spraying of brush on a large acreage can best be done with an air-blast sprayer, mist blower, or by airplane.

At present there are a number of high pressure spray rigs in use for spraying large acreages of brush for the release of seedlings. Their main drawback for this type of work is the large amount of spray solution needed, and the cost of transporting it to back-woods areas. It can be assumed that at least 150 gallons of spray may be required to spray an acre. This means that even with a 600 gallon tank, refilling will be required every 4 acres. This adds up to a considerable amount of down-time and retracing of steps. The high pressure sprayer might be able to cover a swath 60 feet wide without the use of long hose leads and men walking through the brush. This would mean that one-half acre of planting would be run down by the spray rig for every 8 acres sprayed, if a crawler tractor is used to pull the sprayer. Additional hose and men walking through the brush spraying would decrease the amount of run down on a percentage basis, but what loss of seedlings would be suffered from the hose dragging and men walking is not known.

Let us consider, for example, a mist blower developed for spraying 60-100 foot widths on telephone and power line right-of-ways. It has a hose reel which holds 250 feet of ½ inch hose. From our experience with this rig I have calculated that a similar rig could be built up to cover 200 feet at one trip. This would mean spraying 25 acres for every mile traveled, or a loss of 2 percent of the planting run down. One man can operate this rig and run the tractor, I have further determined from the results we have obtained with this type of sprayer that seedling evergreens could be released from brush by spraying in the winter after snow has covered the evergreens. A 2,4-D -- 2,4,5-T mixture in oil would be used. Given one to several sections of land to be sprayed with a minimum of moving around it would be possible to apply the chemical for around 5 to 7 dollars per acre.

There are indications that several other chemicals may have some value in controlling brush competing with evergreens. Any of these chemicals can be applied with a standard high pressure sprayer or with an air-blast machine, with the possible exception of winter spraying.

DISCUSSION

The following information developed from questions asked the speaker:

1. Spray drift has not proved a problem in the northern Lake States because of the general absence of agricultural crops near the area treated.

2. The power sprayers described have been used for custom spraying using 100 pounds of ammate per 100 gallons of water for summer application or 2 pounds of 2,4,5-T and 5 pounds of 2,4-D in 20 gallons of diesel oil for dormant season spraying.

3. Spraying new conifer plantations while they are under snow may be dangerous unless the practice is first put to test. It is known that snow can carry herbicides down to roots or rhizomes in some instances. Holdover effects on new seedlings also have been observed in sphagnum moss six months after spraying.

AERIAL APPLICATION OF CHEMICAL HERBICIDES

M. O. Manuel
Triangle Aviation, Inc.

Our problem can nicely be divided into two parts: (1) the development of chemicals effective in control of brush, and (2) the application of these chemicals. The latter is in my department. As president of the Minnesota Airport Operators' Association, I represent not only our own flight operation but also the entire group of aerial applicators based in this State.

There are two general methods of applying brush killers: as foliage sprays, or by a "basal bark" method. The latter is quite an expensive method and must be done by ground equipment. Normally it is used only on small areas where any drift would be a serious problem. Foliage spraying, on the other hand, we can do with an airplane faster, cheaper and, I believe, better than by any other means.

The first applications of chemical insecticides, weedicides, and brush killers were all made with ground equipment. The physical limitations of slow-moving ground equipment are such that to get even distribution and complete coverage of an acre of land requires about 100 gallons of liquid. So to spread a pint or a quart of chemical evenly over an acre, they simply mix the desired amount of chemical in 100 gallons of water, oil, or some other carrier. Quite naturally the results of the experiments and recommendation for commercial use were based on high gallonage applications. With an airplane such a program is not practical -- so we had to start over. True we were using proven chemicals, but we had to do all the experimental work over, using low gallonage and high concentrations.

This is digressing a little bit, but I think it is an analogy. In the corn borer control, the first recommendations were to use 2 quarts of 25 percent DDT in 60 to 100 gallons of water per acre. So to begin with, we sprayed corn only when the plants were covered with a heavy dew representing about 3,000 gallons of water per acre. However, we ran some tests on dry corn which showed that 2 quarts of DDT in 1 to 4 gallons of total fluid to an acre, gave good borer kills. We found that all we needed was enough water to give us a good emulsion. By direct observation, we found that by using 2 gallons of fluid per acre with a 35-foot swath at 60 m.p.h., at least 98 percent of the total leaves were treated.

Our experience with weedicides is very similar. From the 75 gallons originally recommended for spraying weeds in small grain, it is now standard practice to use 1 to 1½ pounds of 2,4-D in one gallon of total fluid per acre. I believe the same will hold true in brush control, but there are still many things to learn about it. We need to know how much 2,4-D small conifers can stand and how much it takes to adequately control the various species of obnoxious brush.

It is my belief that due to the flexibility of our equipment, many different situations can be handled adequately. In the first place, accessibility by road, of course, is no problem with an airplane. Very large tracts will give us a little more difficulty in accurately marking each individual swath. But that is an operational problem that we ourselves can handle.

The tract that is now waste land is no problem. By using a large amount of brush killer, such as a mixture of 2,4-D and 2,4,5-T, we can take down all of the present vegetation.

The areas which are now completely grown over with brush but which have small seedlings of pine or spruce underneath, I believe we can control by decreasing the pressure on the sprayer and increasing the orifice size. This increases the droplet size so that very few will penetrate beyond the top layer of foliage. Extreme care must be used in the amount of brush killer applied so that little or no damage will be done to the seedling conifers. Such an area will probably require two treatments in successive years. The test plots we sprayed for the School of Forestry and the Lake States Station last summer will give us some leads on this.

The brush area which has an overstory of marketable trees is something for which we have no answer now. It is hoped that the chemical companies will be able to develop a brush killer in the form of a water-soluble pellet that we could apply from the air with our regular dusting and seeding equipment, and which would fall through the foliage to the ground. The first rain then would dissolve the pellet and carry the

chemical into the topsoil where it could be absorbed by the very shallow roots of the brush we are trying to do away with. This is a hope for the future.

For the present, let us say that we can apply liquid either in a very fine mist, a large part of which will penetrate through an overlay of foliage, or in larger droplet sizes, most of which will be caught and absorbed by the overstory. You might visualize this as the difference between a very light rain shower, of which little or none penetrates through the foliage to the ground, and a fog settling on the forest, in which the ground, the trunks, and the stems are just as wet as the top leaves. We are able to vary our pressure from 5 pounds to 60 pounds and still maintain a uniform spray pattern.

Aerial application costs about $2.00 per acre, depending somewhat upon the size of the area to be treated and the distance from a suitable landing area. To this must be added the cost of chemicals and carrier, using probably 1 to 2 gallons of fluid per acre.

A suitable landing area does not necessarily mean an airport. We have often used pastures, tilled fields, and county and township roads which are not too badly obstructed by wires. In order to carry full loads, we would like to have at least 1,000 feet of runway -- and if the obstructions, for instance, are 50 feet high, we need another 600 to 1000 feet after takeoff, in order to clear them. Our wing span is about 35 feet, so the cleared area should be at least twice that in width with a usable surface for the wheels of 10 to 12 feet. These are minimums, but they will give you an idea of what we need.

Sprayers are available either in land planes with wheels or in float planes which will operate off the water. With our pumps set at 10 gallons a minute, we can cover a 40-foot swath at 60 m.p.h. or a 33-foot swath at 72 m.p.h. (depending upon the particular model of airplane), which gives us 5 acres per minute -- or an application of 2 gallons per acre. Our tanks hold 50 to 55 gallons, and the fluid is pumped into the boom with a wind-driven pump. The nozzles are such that even as low as 18 inches off the ground we get a uniform spray pattern. Of course, the higher we fly, the greater the possibility for drift. In spraying for the forest tent caterpillar and also for mosquito control we fly 5 to 10 feet above the tops of the trees and still get excellent coverage. It should be possible to operate in a similar manner in brush control.

DISCUSSION

The following points were brought out by questions from the floor:

1. First year examinations of the cooperative aerial spraying plots near Craigville, Minnesota, showed good top kills of willows, alder,

swamp buckthorn and swamp honeysuckle from 1 to 3 pounds of brush killer applied in 1 to 3 gallons of oil per acre. Resprouting was somewhat greater from the lighter applications.

2. Areas as small as 2½ acres can be treated by airplane spraying; satisfactory marking of the area is the biggest problem.

3. Helicopters are not generally available in the Lake States, but they have been used for brush spraying in the western mountains at costs often lower than for airplanes. Their initial cost is 6 to 10 times that of suitable airplanes.

HAND SPRAYERS

Maurice W. Day
Michigan State College

By hand sprayers, we mean any type of equipment which requires the operator to carry the tank of solution being used. Hand sprayers are familiar to all who have engaged in much woody plant control work, and it does not seem likely that such work will ever be completely freed of dependence on the use of hand sprayers.

Whenever it is possible to lower costs through the use of power equipment or airplane spraying, we are, of course, going to use these cheaper methods. Many situations arise, however, especially in the field of forest management, that will require the use of hand equipment. It does not necessarily follow that such use will be uneconomical, for there are many possibilities of lowering costs through the use of good equipment, efficient work plans and other procedures.

USING HAND SPRAYERS

Hand equipment has the advantage of being flexible to the requirements of the job. Sprayers of this type can be used almost any place the operator can walk. However, they are unsuited for foliage spraying when the foliage is overhead, and they probably should be limited to use on brush less than five feet tall. Most basal stem spraying is done with hand equipment and this use will probably continue.

There are a few problems peculiar to hand sprayers. One difficulty is keeping the equipment in working order. The operators should be trained in the maintenance of the sprayers and should be capable of making minor repairs and adjustments. The problem can be best overcome, in most cases, through the selection of the best made equipment on the market.

Often one of the toughest problems, in a hand spraying program, is that of supply. It follows that economy must be practiced to avoid waste through using more solution than necessary to obtain results. The supply problem probably can be handled best through the use of good work plans which provide for the placing of supplies, so as to prevent undue lost time and back-tracking. In some cases, separate packers may be necessary.

Advance thought should be given to the marking of treatment area so as to avoid both overlapping and missing spots. Sometimes the use of a dye in the solution will prove helpful.

STANDARDS FOR HAND SPRAYERS

Next we might well consider some standards for hand sprayer equipment. First they must be sturdy and capable of withstanding rough usage, without breakage. On the other hand, since they must be carried, hand sprayers should be as light in weight as possible without sacrificing sturdiness.

Probably one of the most important points is ease of repair and maintenance. Nozzles, valves, pumps and other working parts must be easily disassembled with simple tools. Since clogging is probably the greatest trouble, screens and filters should be used wherever possible. Nozzles that have a large screen area are preferable.

One of the disadvantages of hand sprayer work is that it tends to give spotty results and this, in turn, is mainly due to the difficulty of accurately controlling the amount applied to an area. It is apparent that this is mainly a personnel training problem, since the operator himself is the key figure in obtaining a complete and uniform job. This objective, however, can be aided greatly if the sprayers are equipped with precision nozzles that will spray a determined amount per hour at a given pressure. In order that fairly uniform pressures can be used, the spray tanks also must be equipped with pressure gauges.

SAFETY PROBLEMS

This class of equipment does not present many safety problems, but at least two dangers exist that are peculiar to hand sprayer operation. Leaky tanks, or hoses, when using oil solutions, may result in burns to the body of the operator. Clothing soaked in oil can burn the skin when not exposed to the air. The pumping up of sprayer tanks, beyond their safe limit, has also caused accidents which could be avoided through the use of the pressure gauges mentioned before.

TYPES OF HAND SPRAYERS

It would be hard to describe or mention all of the different sprayers now on the market. The most common type is the knapsack sprayer carried over the shoulder by a single strap and pressurized with a self-contained pump. A common variation is a back pack pump, carried on the back like a pack sack, and containing a pump operated, while in place, by a side lever or utilizing a trombone type pump for spraying. These can all be called knapsack sprayers and are suitable for brush control work. The back-pack style is preferred by some, but not by others, and cannot be recommended in all cases.

In Ribes control work, a special type fog sprayer, capable of pressures up to 1,000 pounds per square inch has been used. This sprayer has a capacity of 3-1/5 quarts and weighs 26 pounds empty. It is carried on a back pack board.

For some types of basal treatments, a sprayer is not required. When the solution is to be placed in frill girdles or cups, a long spouted oil can or tallow pot is satisfactory. For basal stem treatments, that call for soaking the bark, a knapsack sprayer, using low pressure and a fan spray nozzle, is probably most satisfactory.

IMPROVING HAND SPRAYERS

None of the hand sprayers is completely satisfactory. Certain improvements and changes are advisable. Probably of most practical importance would be improvements that would make for easier maintenance and repair in the field. Use of better shut-off valves, pumps and gaskets would help greatly. All gaskets and other rubber fittings should be made of oil-resistant synthetics, it would seem. Equipment designers and manufacturers might well keep in mind that all parts of a hand sprayer should be serviceable in the field with a pair of pliers and a screwdriver. A sufficiently great variety of nozzles exist to fill all needs. However, some hand sprayer nozzles are not interchangeable with the regular agricultural spray nozzles as they should be.

Tanks should be equipped with pressure gauges so that there can be some degree of volume control through the use of nozzles of known capacity.

Extension rods might also be improved by being made available in various lengths. Special extension rods for basal stem spraying have been devised and should be popular as this work increases in importance. These extension rods are divided so that two sides of the tree can be sprayed at the same time.

In conclusion it might be said that while there are a number of improvements that can be made to our hand spray equipment, basically we have the equipment at hand to do the work that needs to be done.

SOME BRUSH CONTROL PROBLEMS NEEDING ATTENTION

E. Jankowski
Northwest Paper Company

In past years the brush problem has been discussed from silvicultural, mechanical, and other viewpoints. I believe this is the first time the subject of chemical brush control has played such an important role on the agenda of a foresters' meeting in this region.

DEVELOPING SUITABLE CHEMICALS

The first problem of brush control that needs our attention, in my opinion, is that of developing a chemical or a group of chemicals to accomplish the results we want. Unfortunately, most of the chemicals used in controlling brush today have been developed for groups other than foresters. It is not too surprising, therefore, that foresters feel that they do not have chemicals designed for their specific needs.

To spur research in this field, we must cooperate with the organizations responsible for the development of chemicals, usually the larger chemical-producing companies. We must show these companies that we do want, and we do need, certain types of herbicides. We should be willing to make trial runs of newly developed formulae. We should also give some assurance that, if an herbicide is proved successful, the potential market for this may be sufficient to warrant considerable research expense. In the past foresters have not given too much encouragement to the promotion of chemical herbicide development.

What are some of the basic characteristics of a desirable brush control chemical? I think, first of all, that such a chemical should result in a permanent kill of the species of vegetation being controlled with no sprouting. Specific or selective chemicals should be developed for each species or group of species of vegetation being controlled.

I believe this last point to be of especial interest to foresters who can visualize the eventual development of chemical controls far beyond the mere control of brush. Probably the greatest potential use of chemical sprays will be to alter the species composition of our forest stands. The removal of birch and aspen from our balsam-fir stands, the removal of scrub oak from our jack pine stands, or the removal of other undesirable tree species from any stand, may prove to be the greatest future outlet for chemical sprays. By the development of specific sprays, it might be possible, for example, to kill hazel and alder brush, while leaving intact the desirable species of browse, to support a local deer population.

APPLYING THE CHEMICALS

How is the chemical going to be applied? That is the second problem. I think that the chief advantage of chemical control over other methods is the fact that for the first time we are dealing with a method of brush control which can be applied in a number of ways — including aerial sprays. No doubt there will always be a place for ground methods of application, but to confine ourselves to such cumbersome and costly methods will result in covering only a fraction of the area that could otherwise be treated. In my opinion, to have widespread use, any brush control chemical must be adapted to aerial application.

To my knowledge, many of the areas most in need of brush control are those on which ground methods are out of the question. Consider, for example, the brush problem of the birch belt, along the Echo Trail, or the alder brush problem on many of our most productive spruce sites. Also, in the Central Pine Region of Minnesota, the removal of oak from a dense oak-jack pine stand would require the use of aerial sprays.

Apparently, the greatest objection to the use of aerial sprays is the thought that foliage sprays are not effective in the control of brush. This may well prove to be true, but certainly not enough evidence has yet been gathered to support such a thought. No doubt aerial application of sprays will present new problems — problems which can be solved with experimentation and research. For example, the spraying of the two experimental areas in northern Minnesota two years ago was generally considered to be unsuccessful. Yet, even this small amount of experimentation served to disprove the common belief that it might take hundreds of gallons of spray solution to treat an acre, making the procedure impractical. Furthermore, this experiment proved that aerial application would do very little damage to a young jack pine plantation, and also, that the use of two gallons of spray per acre would kill scrub oak. We must be careful not to condemn a practice before it has been properly tried.

REDUCING COST OF CHEMICAL CONTROL

The third problem needing attention, as I see it, is that of bringing the cost of brush control down to a point where it is economically feasible. Just how much one will be able to pay for chemical control will, of course, depend upon the results obtained. We may be willing to pay but a dollar or two per acre to prepare a site for planting by eliminating brush. On the other hand, we may be willing to pay several dollars to obtain a satisfactory release job on a young plantation or on an older plantation being overtopped by hardwood species. Perhaps a figure of twenty dollars or more would be in keeping with the value received in similar instances. One thing appears certain at this time: the widespread use of aerial sprays will very likely bring the cost of brush control down to a figure far below any method of control now in general use.

To summarize then, the major brush control problems as I see them are first, to develop a chemical to do the job we want done; second, to have this chemical applied by aerial means; and third, to bring the cost of control down to what we can afford to pay.

These problems will not be solved easily nor quickly but their solution will mean a tremendous stride toward better silviculture in this country.

SOME WOODY PLANT CONTROL PROBLEMS NEEDING ATTENTION

L. M. Argetsinger
William Bonifas Lumber Company

From an operating pulpwood point of view we tend to think along the following lines:

1. Under what forest conditions might a pulpwood forest manager consider chemical herbicides?

   A. On sites where conifers compete with alder, willow, birch, or hazel for growing space, the conditions would seem to be ideal for the use of herbicides to release the balsam-spruce-cedar. From critical examination of many such areas with this form of release in mind our men have observed:

      1. On some areas the brush is heavy and only an occasional conifer is to be found.

      2. On some areas the conifers have attained a dominant position and the brush is not effectively retarding the conifers.

      3. No area of size sufficient to justify aerial spraying has been found where a reasonable stocking of conifers exists under a cover of undesirable brush species.

      4. In recent cut-overs there may be a brief period when conifers and brush struggle to occupy the recently opened up soil areas. Such areas will be spotty and the length of time when herbicides can be used to effectively release the conifers is short.

   B. Spruce in plantations frequently takes a period of time to become established before it commences appreciable height growth. During this period selective herbicides can be used effectively and economically to control woody brush.

   C. Removal of cull stems - Following cutting operations one finds a considerable number of cull stems of any of several species which have normally been abandoned and continue to occupy growing space though they grow no commercial wood. Intensification

of forest management will call for the elimination of these culls. Herbicides may well provide the economical answer to that problem.

2. What are the limitations of some of the equipment for applying herbicides?

   A. Foliage Sprays

      1. Back pack tank sprayers are satisfactory for small areas near roads. Brush higher than 8 feet cannot be effectively reached with a foliage spray by this method. To get adequate coverage will require a minimum of 20 gallons of spray mixture per acre. The labor cost of toting supplies and spraying would be excessive except on small favorably located areas.

      2. A trailer sprayer or tractor mounted sprayer would be limited as to the areas which it could cover because the areas to be sprayed usually would be poorly roaded young stands. Satisfactory coverage would require a minimum of 20 gallons of spray mixture per acre. The cost of application is likely to be high.

      3. Aerial application of herbicides seems to be cheap and practical as long as the areas can be kept to 5 acres minimum size and grouped sufficiently for practical flying operation from the base airport. By aerial spraying near Craigville, Minnesota, the hardwood brush was effectively controlled with a spray mixture which totalled one gallon per acre at a reported cost of $3.60 per acre.

   B. Stem sprays for effective and economical control of cull stems need to be developed. It would be preferable to use an herbicide like 2,4,5-T which would not necessitate use of frilling or girdle cuts.

3. Use of small amounts of herbicide (1 pound acid equivalent) and small volume (1 gallon) of spray mixture per acre is relatively new in the field. Spreading the herbicide so lightly over an area we need to determine again:

   A. The effective kill by plant species.

   B. The most effective carrier. Water - Oil.

   C. The differences due to season of application: spring flushing, midsummer, fall or dormant.

   D. The amount of sprouting and root suckering following killback of hardwoods.

WOODY PLANT CONTROL PROBLEMS NEEDING ATTENTION ON STATE-OWNED FOREST LANDS

Earl Adams
Division of Forestry, Minnesota Conservation Department

The woody plant control problems of the State of Minnesota, though not appreciably different from those of other owners of forest lands, are almost as varied as are the forest conditions found on state lands. With the large forest land acreage in state ownership, we probably have represented just about all of the forest conditions to be found in Minnesota.

Specifically, however, I believe our major problem is the adequate regeneration of the rather extensive area of overmature and decadent stands that, for one reason or another, have gradually fallen apart before they could be harvested. This slow process of decadence seems to have been ideal for the invasion of brush almost to the exclusion of tree species. Three types immediately come to mind as particularly representative of this problem. These are spruce-balsam, jack pine, and Norway-white pine. These brushy areas contain scattered remnants of the original stand and a few stems of desirable reproduction of tree species. The seed source, in most instances, is there and will, I believe, successfully regenerate the stand if the brush is eliminated. Some minor attempts have been made to eliminate brush in mixed spruce-balsam and white pine stands by disking, but the physical problem of sufficiently breaking up the large stemmed mountain maple and hazel growing among the windfalls with the equipment we had available, has somewhat discouraged us. We are, therefore, watching Dr. Henry Hansen's chemical brush eradication experiments in the pine stands of Itasca Park with considerable interest and hope.

In jack pine, the brush problem is not solely confined to decadent stands. Forest managers, who plan to harvest jack pine on 60 to 70 year rotations, are generally agreed on the desirability of fairly heavy thinning cuts made periodically to remove low vigor trees. On better sites, thinning and invasion of brush, principally hazel, go hand in hand. Consequently, we, in the Division of Forestry, approach thinning with not a little fear, because we cannot be sure that the brush can be satisfactorily and economically eliminated when attempts to solve this problem by the use of herbicides have been made. However, we have tried disking, and though the initial catch of jack pine was encouraging, the heavy growth of annuals and the resprouting of the hazel appears to offer more competition than the seedlings can stand. The fact that reproduction was evident following removal of the brush cover is encouraging, and further work will be carried on when funds are available. We cannot pass by jack pine without making some mention of the scrub oak competition encountered on state lands in the Park Rapids and Brainerd area. Some method must be found for low cost removal of this inferior species so that jack pine and Norway pine can take its place.

It has been my personal observation that tamarack stands on better swamp sites, such as are found in the big swamps of Koochiching County, are not reproducing themselves very satisfactorily. These stands, which I believe became established after fires, are choked with alder. Little reproduction is evident and cutting, in most cases, seems to do little more than encourage alder growth. Other factors may be contributing to this lack of reproduction, but I think that brush competition is most important.

Another brush problem encountered on state lands is found in swamps where only scattered black spruce are growing in dense brush cover. I am not sure of the exact reason for this condition, but I suspect that it is a tamarack site which failed to regenerate, except for a few spruce. Our state appraisers have mentioned a number of such stands in which they would like to sell the spruce, because it is mature and blowing down, but they are always faced with the problem of dense brush and lack of reproduction. Some similar conditions have been noted on the good spruce sites found on shallow peat and swamp margins after cutting. Here again, other factors may contribute to the lack of reproduction, but I suspect brush competition is largely responsible.

Finally, I would like to mention the problem of what to do with the deforested brush areas. Much of this area supports some reproduction of desirable tree species, and would, I think, regenerate naturally if a cheap method of removing brush competition were found. The rest of the deforested brush area must be regenerated by planting after successfully removing the brush.

In review, our woody plant control problems are found in overmature stands, particularly spruce-balsam and pine, in jack pine stands which are thinned, in the better swamp sites and in the extensive deforested brush areas. These problems are encountered daily in the management of the forest lands owned by the State. One answer seems to apply to all -- that is brush eradication by an economical and practical method, if a long brush cycle is to be avoided.

DISCUSSION

Discussion emphasized that on disked areas annual plants are the principal source of competition for tree seedlings for the first two or three seasons, but that resprouting woody plants become a problem after about three years.

SOME WOODY PLANT CONTROL PROBLEMS ON THE NATIONAL FORESTS

D. Bulfer
Nicolet National Forest, U. S. Forest Service

On the Lake States national forests, as on other forests in the region, important tasks have been (1) the planting of unstocked and poorly stocked stands; (2) the improvement of badly decadent stands that have followed clear cutting and burning; and (3) more recently and to a lesser extent, the securing of adequate reproduction of desirable species following harvest and regeneration cuts.

I believe our number one problem is that common to getting any new process or method into general use and application, especially during the developmental stage when research has found only partial answers, when drastic improvements are continually being made, and when the forest manager cannot be reasonably sure of the results he may expect.

Specifically, some of our woody plant control problems on the Nicolet National Forest in northeastern Wisconsin are as follows:

1. Planting. Scrub oak, decadent poorly stocked aspen areas, hazel, tag alder, and other weed and off-site tree species occupy several thousand acres of national forest land that should be planted. To do this job by the time honored method of mechanical control of these species is tremendously expensive. After ground preparation, two and sometimes as many as three release jobs are necessary. This adds up to prohibitive costs of from \$40 to \$60 and even more per acre. Few such areas are now being planted. The Lake States Station has demonstrated that alder can be controlled by foliage sprays at, I believe, about \$10 per acre. Likewise it has been possible to retard the growth of hazel and aspen in a similar manner. Can we look forward within the reasonably near future to a foliage spray which can be applied by aircraft to extensive areas and tractor or truck tankers for smaller areas that kill enough stems and retard sprouting sufficiently to permit the successful planting of such areas?

Failing in that, can we hope for chemicals sufficiently selective to permit a foliage spray that will retard or kill sprouts of aspen, oak, etc., over pine, for example, without critical injury to the pine?

Failing in that, what can we expect of basal sprays? What chemicals and concentrations offer the best results? At what age can basal sprays be used on aspen and other species to best advantage and how long or how permanent will be the results?

2. Plantation release. Plantation release on the Nicolet now is one of our major projects. We are spending over \$20,000 annually in releasing red pine and, to a lesser extent, white pine and spruce, from overtopping aspen. It will take about three more years to complete this job. Most of these plantations were planted in the 30's and

early 40's by CCC. Some of these areas should possibly have been planted to spruce. Some of them might possibly have best been left in aspen. Just to illustrate its magnitude, I might give you a general size-up of this job on the Nicolet. While our records do not permit giving you a complete picture, it is about as follows:

a. We have over 78,000 acres of successful plantation.

b. About one-half, or 39,000, are red pine of which about 15,000 acres have been released since the war and approximately 9,000 acres more are to be released during the next few years. Essentially all of this work has been by the time honored method of cutting with various edged tools.

c. A very large percent of these plantations were released from two to four years after planting.

d. About 7,000 acres are being released through the commercial cutting of aspen. In many areas, further release will be required from the dense, vigorous sprouting that will result.

e. Several thousand acres have been lost to overtopping scrub oak and aspen.

f. Some 10,000 acres needed only one early or low release.

We have put in a few test areas using ammate crystals in frills and ammate solution in the Cornell tool. This winter we are trying "Brush Killer" with an oil carrier as a basal spray on aspen which is about 2 inches in diameter. In using brush killer as a basal spray we found we did not have appropriate nozzles for our spray guns. We wonder how much effect, if any, the snow will have. While the aspen is predominantly 1½ inches in diameter, there are some larger unmerchantable trees 8 to 10 inches in diameter that basal spraying may not kill. This means we must take a cutting tool or some other chemical along, with resulting crew organizational problems.

Basal sprays appear to offer real possibilities. If they prove to be economical and effective they will lengthen the work season and should eliminate or reduce sprouting.

All in all, however, results have not been encouraging. Costs have been high and results have been spotty.

3. Stand improvement work. On the Nicolet we have about 180,000 acres of mixed hardwood stands, predominantly rather decadent, which have followed fire or logging. They are badly in need of improvement.

Fortunately, good markets plus the power saw permit our harvesting as little as 500 to 750 board feet per acre, depending upon accessibility of very poor quality saw timber and requiring the sale operator to fell

or girdle a reasonable number of cull and wolf trees. Unfortunately a market for fuelwood and chemical wood does not exist. We are spending $3,000 to $4,000 a year for felling and girdling cull wolf trees, cull chemical wood trees, and weed trees such as ironwood, in an effort to improve these hardwood stands. We are covering possibly 1,200 acres a year in this manner.

Experimental work in the thinning or crop tree release of dense young hardwood, 15 to 25 years of age, shows it to be extremely good business. The power saw, axe, and better than average markets have enabled us to make some progress. The general semi-chemical pulping of northern hardwoods, as well as aspen, would virtually solve this problem. The acreage is so extensive and the values involved are so great that intensive work of this nature would be done if chemicals could be found for doing the job economically.

As I view the problem, we need a chemical and method of application as a basal spray that will kill woody plants of any species or size, at least up to 8 or 10 inches d.b.h. and do the job cheaper than the axe or power saw.

4. Right-of-way and recreational area maintenance. While possibly not a part of forest management or pure silviculture, the control of woody plants along our roads, under our telephone lines, and in our public recreational areas, especially those located in the hardwood type, are real problems. Here the job is to convert to a permanent grass cover.

On the Nicolet alone, we maintain about 350 miles of forest roads and there are some 400 miles maintained by the towns and state. Periodic brushing of these roads is very expensive. There are several hundred miles of logger-built roads that are lost to encroaching tree growth. We also have about 125 miles of telephone line. Again the periodic brushing of these lines is expensive.

There are several winter sports areas in the Lake States with ski slopes and runs where it is desirable to convert hardwood and brush to a permanent grass cover. Likewise a considerable amount of such conversion is desirable at many public use areas located in the northern hardwood type.

We have done some chemical control work along our roads and telephone lines using "Esteron Brush Killer" and "Brush-Off," or "440 Brush Killer" with water as a carrier and applied as a foliage spray, with and without the cutting of the larger woody plants over 8 to 15 feet tall. Results have been encouraging and costs have been reasonable, running about $9.50 per acre or from $10 to $18 per mile of right-of-way.

Felling trees over 10 to 12 feet in height, followed with a foliage spray one year later, and spot-spraying a year or two later, appears to be one acceptable approach, especially along roads and other areas where aesthetic values are high. In back areas, I believe aesthetic values

are not important. Possibly physical limitations and costs only govern the size of tree that can be killed.

Some of the problems or questions that appear to exist are:

a. Which is more economical - 2 treatments at 1- or 2-year intervals with a weak solution of acid or 1 heavy application to be followed up with later spot treatments?

b. What equipment is best suited? Are high pressure (200 pounds plus) or lower pressures (75 to 150 pounds) better?

c. What type of nozzle and boom is most economical? Sprays applied by conventional equipment do not penetrate laterally through dense foliage.

d. We have found that phenoxyacetic and similar acids damage rubber and leather pumper parts. Changes in make-up of the chemicals or resistant pump parts are needed.

e. What are the possibilities of completely sterilizing narrow strips which will serve as firebreaks along roads and other high risk areas in hazardous and valuable forest types? Some work has been done on this, but I do not recall the results as having been conclusive or that the costs were substantially less than the conventional method of disking or furrowing.

I believe we foresters have a new tool of great promise at our disposal, but we do not yet know how to use it well. The tool itself needs substantial improvement and extensive use before it can be perfected. This may prove to be very costly.

WOODY PLANT CONTROL PROBLEMS NEEDING ATTENTION

T. Schantz-Hansen
School of Forestry, University of Minnesota

It is not difficult to sit down and dream up innumerable problems needing attention in the field of woody plant control in the field of forestry. The difficulty arises in judging which problems are the most important and how the studies should be carried out. In my opinion woody plant control can be divided into three broad classes: (1) Chemical control, with which this conference is concerned and which has been the subject of many studies in recent years; (2) Mechanical control, which received quite a lot of attention before the development of the various chemicals; and (3) Controlled burning, which practice is used in some other forest regions but to date has not been used here.

I shall mention just a few problems which need attention and shall make no attempt to outline how they should be done nor to state which should be done first.

1. We need to develop an efficient machine for applying chemicals in forest stands before cutting. Turbine sprayers, boom type sprayers, and some nozzle or gun type sprayers are not too efficient in timber stands.

2. We need to develop a coloring material which can be added to the spray solution so that the operator on a large-scale job can instantly judge the coverage he is getting. There are some such materials available but they do have a tendency to clog nozzles.

3. We need to develop a chemical which can kill underground stems of hazel and alder and yet not be too drastic.

4. We need to study the problem of annuals, perennials, and grasses which nearly always come in following successful spraying jobs. These are often as much of a hindrance to natural regeneration and plantings as the original stand of brush.

5. We need further study on the problem of release of plantations and natural regeneration by chemical means. This would involve a study of the season during which it could be done, the age of the stand to be released, and the chemical to be used. In our early work we found that the sodium salt of 2,4-D was not too drastic for well-established young conifers. I understand that this salt is no longer manufactured in quantity.

6. We need some way of translating the work done on small plots to large-scale areas.

7. We need to know something about the height growth of resprouting brush species top-killed by the chemical. It may be that the rate of growth is slowed up enough to make planting possible.

8. We need to develop more efficient machinery for the mechanical control of brush.

9. We need to study the efficiency of a combination of methods such as disking followed by spraying or vice versa.

10. We need to study a combination of burning and spraying or vice versa.

11. We need to know just how complete a job it will be necessary to do in order to reach our goal.

12. We need to know how much it will cost to reach that goal.

13. And last, but not least, we need fundamental studies in the physiology and ecology of all species which we are trying to control.

WOODY PLANT CONTROL FROM THE VIEWPOINT OF AGRICULTURE

A. H. Frick
County Agent, Itasca County, Minnesota

Land clearing has been a major problem of farmers in Itasca County for over 30 years. It is still an important problem in that area, where most farmers as yet have a very inadequate acreage of plowland.

In the early days, controlled broadcast burning and dynamiting of stumps were among the more common techniques used. More recently, mechanical methods have been used with some success. These include bulldozing, use of large disks, and a new machine called the "Bushwacker" which clears in one operation.

Land clearing with herbicides has also been tested on a fairly wide scale. Back-pack pumps have been used for such work in most cases, with the farmer treating brush patches and small trees individually. After this vegetation has rotted for four or five seasons, the area can be plowed up.

Aerial spraying for land-clearing purposes has been tested on a small scale in Koochiching County. Selective herbicides are not necessary, since the farmer wants to dispose of all woody vegetation. Results of this test look fairly promising. Here again, the plan is to pasture such lands for four or five years prior to plowing.

SOME WAYS IN WHICH FOREST INDUSTRIES CAN HELP SOLVE WOODY PLANT CONTROL PROBLEMS

B. L. Berklund
Nekoosa-Edwards Paper Company

This is a chemical control meeting but I wish to generalize enough to cover the whole field of forestry research.

Ways in which industry can help solve these problems can best be stated by summarizing some of the things industry is doing. Solution of these problems can be aided by expansion of the points below:

1. Industry (and other large land holders) is a logical source of problems needing attention. Industry is always in a good position to bring practical problems to specialists and is doing a good job in this respect.

2. Industry can go one step further by providing funds for fellowships in graduate research at institutions. This is particularly important for fundamental academic studies which may later be applied in practical problems. Many industries now do this.

3. Provide for cooperative research.

   a. Manpower, equipment, and material for large data collecting jobs.

   b. Aiding investigators in special arrangements involved in (a) above, etc.

   c. Provide for trial cost studies of research procedures. Pooled cost studies should provide better data than those resulting from studies and costs by one agency.

   d. Provide land areas for field laboratory space.

4. Conduct research.

Every industry could profit by adding to their staff a forester who has done a field research problem. Such a man is in a position to foresee problems involved in research. He should prove of value in selection of problems to be attacked and he should be allotted time to cover literature review. If such a man has not been added, some staff member should cover the above functions.

5. Create an atmosphere favorable to the conducting and acceptance of forestry research within a company or its forestry department if such an atmosphere is needed.

6. The biggest job of all (a manifestation and application of item 5) is to sell forestry research findings to our own foresters and companies. There is undoubtedly good research work today gathering dust on shelves because it has not been "sold." Research loses its value if applicable information is not used.

GRADUATE STUDY AS A MEANS OF ACCOMPLISHING WOODY PLANT CONTROL RESEARCH

F. H. Kaufert
School of Forestry, University of Minnesota

The discussions and papers of the past two days indicated how broad and complex are the problems involved in the control of woody plants by chemicals and other means. When one considers that the application of most of the present herbicides has been a development that has taken place largely during the past ten years, the extent of the progress made is truly remarkable. Yet, it is quite evident from the questions that have been raised and the information that has been presented that for every problem we thought we had ten years ago we have opened up ten new ones to which we want answers today. This situation is not unusual.

It is characteristic of every field in which there is a great deal of activity. It is a healthy situation and indicates growth and vigor. We should be encouraged rather than discouraged by this recognition that we are faced with more problems to which we should like to have answers than we can reasonably visualize solutions for, even though our total research effort be multiplied many fold.

If answers were available for all of the questions and problems in this field there would be little point in the present meeting with its stimulating discussions and frank acknowledgment that our lack of knowledge far outweighs our store of knowledge. This lack of knowledge should be a challenge to everyone working with herbicides, whether he be the man who handles the nozzle on the actual spray job, the forest manager, land manager, research forester, research chemist of chemical companies, or instructor in institutions training foresters and other plant scientists. It gives each of them an added role in the job of attempting to unravel some of the uncertainty and to find reasons for practices evolved through trial and error.

It is because the problem is so broad and includes so many unknowns, some of which are applied and of evident immediate practical nature whereas others are strictly of a fundamental nature, that the whole subject of woody plant control through chemicals is so appealing to forestry schools emphasizing graduate study programs. As emphasized by Mr. Beatty and several other speakers earlier on our program, the solutions to some of our fundamental questions can determine to a considerable extent what can be done practically. When knowledge of where, when and how food is stored in plants, information of the relationship of rate of defoliation to absorption of herbicides, absorption of herbicides through bark, formation and extent of dormant buds, inhibition of bud formation by absorbed herbicides, and numerous other fundamental considerations that have been touched on in the past two days can constitute the solution for very practical problems, then there should be little question in anyone's mind relative to the need for fundamental research along with the trial and error of applied research.

For a field of work to be suited to graduate study requires not only that it be broad and have numerous applied as well as fundamental problems associated with it, but also it involves several added important considerations. First, the administration of the institution must be interested in and sympathetic to the research program if it is to achieve even a modicum of success. Without such understanding and support, progress can be discouraging indeed. Secondly, the institution must have access to all the knowledge available on the subject, not only through libraries and printed material but through close contacts with research workers interested in the same general problem, but with possibly a somewhat different direction of effort. Those of us interested in the woody plant control field have much to learn from the host of workers in such fields as agronomy, horticulture, range management, etc. If we can benefit from their experiences, whether their

effort has resulted in successes or failures, we will be just that much further ahead. Third, the institution desiring to conduct graduate and staff study in this field, must have on its staff qualified and competent, deeply interested, and enthusiastic staff members with ideas, imagination, and the patience of a mule trainer. This is not to insinuate that graduate students resemble mules. This is far from the case. Generally they are the outstanding young men of their class, with enthusiasm and vigor to burn and with ideas of their own. Not to suppress these fires but to guide them on courses that will result in accomplishments meriting the Master of Science or Ph.D. degrees in reasonable periods demands patience and judgment. The fourth consideration is the availability of interested and qualified graduate students. Actually, this can be the most important point of all. A glance at the bulletin board to the right of the entrance to this auditorium will convince you of what is involved. There are more fellowships and scholarships available in U. S. schools of forestry today than there are interested and qualified graduate students. A school without a goodly supply of scholarships does not stand a chance of building a graduate study program in any field of forestry at present. The fifth requirement is that of facilities and funds. Because the field of woody plant control research is so broad, there are problems to fit practically any interested institution's pocketbook and equipment. However, the better equipped and financed institutions will have many advantages in attracting graduate students.

Because we feel that our situation at Minnesota comes reasonably close to fulfilling most of the above enumerated requirements, we have emphasized the field of woody plant control through chemical and other means in our graduate training and research program. We are fortunate in having an administration that is aware of the problems of this field and cognizant of its potentialities for development. Associated with us on the St. Paul Campus are several groups that have pioneered in the application of herbicides to agricultural crops. A member of our staff is an active member of the Weed Control Committee that functions on the St. Paul Campus. Several of our staff members have taken a particularly deep interest in this field and have maintained close contact with developments. Dr. Henry Hansen's functioning as summarizer of research on chemical control of woody plants for the North Central Weed Control Conference has been a contribution the School of Forestry has been happy to make. It may actually be more of a credit to him than to the School because much of the work has been done on his own time. It has kept us abreast of developments and thus has been of real value to us. We have also been fortunate to have during the past five years, a considerable group of fine young graduate students interested in this field of research. However, providing these young men with financial support so necessary today has been a matter of borrowing, begging, yes, occasionally even stealing, from other projects and support items. We hope that in the future this important shortcoming of our program can be corrected so that added funds from appropriations, Graduate School grants, and industrial fellowships will be available directly for this work.

Excellent facilities, both for laboratory or field work, are available for graduate research studies in this field. There certainly is no lack of brush at such places as the Cloquet Experimental Forest or Itasca State Park where some of our research is centered. Nor is there lack of field material for research on the millions of acres of publicly owned land where studies are welcomed.

In the past five years 8 graduate theses have been completed or are in the process of completion in the School of Forestry on fundamental and applied problems in the field of woody plant control. Four of these have been fundamental studies on the ecology and other basic questions relating to such important brush species as hazel, prickly ash, wolfberry, and alder. Although none of these studies has given us all of the answers or the important fundamental information needed before we can hope to solve many of the practical problems involved in the control of these species, they have been very significant contributions and about the first of their type ever made. Four of the theses completed or in progress relate to the control of brush or other noxious weeds by means of chemicals. The work done with TCA in forest tree nurseries has already found important application.

In conclusion, let me say that this conference has been a real stimulation. To see foresters, chemists, and others sit down together and discuss mutual problems with understanding and a common objective in mind can result in nothing but progress. This is an active and important field of research for foresters as well as applicators and chemical producers. It lends itself particularly well to graduate and staff study, and we at Minnesota plan to push ahead in this field through graduate study programs, staff research, and cooperative study programs with other public agencies and industries. It is a field in which we should welcome every possible research effort, whether this be by industries, public agencies, or other interested individuals. It is a field that will demand the maximum of effort and cooperation by everyone if real progress is to be made.

ATTACKING WOODY PLANT CONTROL PROBLEMS THROUGH COOPERATIVE RESEARCH

M. B. Dickerman
Lake States Forest Experiment Station

The idea of cooperative research is one that has much to offer in the field of woody plant control. Currently the Lake States Station has some 40 cooperative research projects under way. From the experience in working with industrial foresters, I strongly recommend that future projects in woody plant control be on a cooperative basis. In this way the best skills and facilities of all parties can be put to work effectively with a minimum expenditure.

What do we mean by cooperative research? In general, the idea is that a number of parties undertake a project jointly, each making a contribution of one form or another. For example, in Michigan, working with the Dow Chemical Company, a number of herbicides have been tested on sample plots. The Dow Chemical Company provided the chemicals and participated in the design of the study. The Lake States Station installed the plots, made the necessary records, and analyzed the results. In northern Minnesota the work in airplane spraying is a good example of what can be done cooperatively. Our Station's Annual Report for 1952, which will be out soon, cites numerous examples of cooperative research and how it works. From the report you will also get a good summary of the work the Lake States Station currently has under way in the field of woody plant control.

Cooperative research projects work in well with both University and Station activities. Such institutions have specialists trained in experimental design, have access to laboratory facilities and literature, and from experience in related fields there is often opportunity to make valuable suggestions in carrying out new studies. On the experimental forests there are numerous opportunities to utilize areas for testing certain herbicides. Frequently all that is needed is field assistance. Likewise, the same opportunity exists on some company-owned lands. By using standard work plans, replications of studies can be installed by various cooperators at their convenience. Yet in the final summation of such work, since a standard plan was used, it is possible to analyze results with much more data at hand and thereby give greater validity to the findings.

Experience to date indicates, though, that certain things are essential in cooperative undertakings. First, I would stress a common desire of all concerned to seek knowledge about a particular problem regardless of what the impact of the findings may be. Second, I would stress that each party to a cooperative project should make a significant contribution, not just a token one. Third, it is often helpful to spell out clearly what each participant is to do and when. In dealing with large companies and with public agencies we all recognize that personnel changes as men take on new assignments or move to other areas. By specifying in writing what the responsibilities of each organization are, new personnel can understand them clearly and the chances of a project not being completed are minimized.

Many of the speakers on the previous panel have enumerated problems needing attention. It is quite obvious that the facilities now available to the Universities and this Station will not permit coverage in the near future of all the problems. Some of the projects, such as a study of the effectiveness, costs, etc. of aerial spraying, ways and means for more effective application by hand and power methods, how to control hazel brush and heavy grass, use of chemicals in thinning of jack pine, and the removal of scrub oak are all good possibilities for cooperative research. Which projects to undertake needs to be carefully considered from the standpoint of priority and facilities available to get such work under way.

I assure you, though, that any and all offers for cooperation are most welcome, and, where feasible, they will be put to good use. There is still room for more cooperative research in the Lake States, and such meetings as this are one way of getting a full understanding of the needs and possibilities of such work.

SOME CURRENT PROJECTS IN CHEMICAL CONTROL OF WOODY PLANTS IN THE LAKE STATES

At a request from the floor, participants in the clinic listed the following projects as currently or recently under way:

J. H. Stoeckeler - Lake States Forest Experiment Station, Rhinelander, Wisconsin.

1. A test of phenoxy compounds and ammate for the control of swamp alder.

2. Tests of various chemicals and techniques for the control of scrub oak (in cooperation with Nekoosa-Edwards Paper Company).

3. A test of several chemicals in the control of a number of woody plants along right-of-ways on the Nicolet National Forest.

J. L. Arend - Lake States Forest Experiment Station, East Lansing, Michigan. (All projects are cooperative.)

1. Use of ammate in cups to control scrub oak.

2. Tests of 2,4,5-T basal sprays at various heights in control of oaks, red maple, and aspen.

3. Tests of volumes, concentrations, and seasons of application of chemical herbicides.

4. Sweet fern control tests with hormone herbicides.

5. Tests of frill girdling treatment with 2,4,5-T on oaks, red maple, and aspen.

6. Aerial spraying of scrub oaks with 2,4,5-T.

E. I. Roe - Lake States Forest Experiment Station, Grand Rapids, Minnesota.

1. A test of chemicals, concentrations, and season of application in foliage spraying of hazel.

2. Repeat spraying of hazel with 2,4-D.

3. Cooperative test of aerial spraying of swamp shrubs on a former spruce site.

4. Tests of herbicides on bog shrubs (Labrador tea, leather leaf, swamp laurel).

5. Basal sprays of mountain maple.

6. Release of conifer seedlings from hazel with phenoxy compounds.

7. Release of planted and natural pines from large tooth aspen suckers with 2,4,5-T and 2,4-D foliage sprays.

H. L. Hansen - University of Minnesota, School of Forestry, St. Paul, Minnesota.

1. Graduate studies in the ecology of brush species (hazel, prickly ash, wolfberry, and alder).

2. A study of the interrelation of brush and deer in the conifer region of Minnesota.

3. Tests of the tolerance of conifers to various herbicides.

4. Cooperative aerial spraying of scrub oak at Brainerd, Minnesota.

T. Schantz-Hansen - University of Minnesota, Cloquet Experimental Forest.

1. Tests of various herbicides in the past to bring in natural regeneration or facilitate planting.

2. Plan to test spraying of hazel under jack pine, and to contrast this with controlled burning under mature red pine and on cut-overs.

Maurice Day - Michigan State College, Dunbar Experimental Forest.

1. Tests of herbicides to kill white pine.

2. Thinning of balsam fir with herbicides.

3. Tree-debarking with sodium mono-chloro acetate.

John K. Kroeber - Bureau of Entomology and Plant Quarantine, White Pine Blister Rust Control Division.

1. Dormant spraying with oil, and 2,4,5-T being tested on several resistant species of Ribes.

2. Cooperative work with Dr. Melander on formulations for Ribes control.

Mr. Kroeber also outlined some of the problems encountered in using

herbicides to control Ribes. There are seven different species common to this region, and many of them can be successfully controlled with 2,4-D or 2,4,5-T. Skunk currant and swamp red currant are very resistant to these herbicides.

SOME RECENT REFERENCES CONCERNING CHEMICAL CONTROL OF WOODY PLANTS IN THE LAKE STATES

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ATTENDANCE AT LAKE STATES FORESTRY CLINIC
St. Paul, Minnesota
February 10 and 11, 1953

Forest Industries

Philip B. Thomas	Wm. Bonifas Lumber Co.,	Neenah, Wis.
L. M. Argetsinger	Do.	Marquette, Mich.
C. A. Samuelson	Do.	Iron Mountain, Mich.
B. L. Berklund	Nekoosa-Edwards Paper Co.,	Port Edwards, Wis.
R. C. Dosen	Do.	Do.
George J. Brabender	Marathon Corporation,	Rothschild, Wis.
Bruce G. Buell	Northern Paper Mills Co.,	Green Bay, Wis.
A. P. Chapman	North Star Timber Co.,	Duluth, Minn.
Charles N. Davis	Mosinee Paper Mills Co.,	Solon Springs, Wis.
Frank N. Fixmer	Do.	Do.
Terrence F. Michal	Do.	Do.
R. C. Hammerschmidt	Cliffs Dow Chemical Co.,	Marquette, Mich.
William R. Howe	Escanaba Paper Co.,	Manistique, Mich.
John W. Hubbard	M&O Paper Co.,	Big Falls, Minn.
Ed. Jankowski	Northwest Paper Co.,	Cloquet, Minn.
Glen Johnson	Do.	Do.
Don Pierce	Do.	Do.
J. W. Macon	Consolidated Water Power and Paper Co.,	Rhinelander, Wis.
King Sheldon	Rhinelander Paper Co.,	Do.
Ward Smith	Do.	Do.
Wm. P. Yost	Flambeau Paper Co.,	Park Falls, Wis.

Universities and Colleges

Parker Anderson	University of Minnesota,	Extension Forester
J. H. Allison	Do.	School of Forestry
Bruce Brown	Do.	Do.
Henry Hansen	Do.	Do.
Wm. Hsuing	Do.	Do.
R. A. Jensen	Do.	Do.
F. H. Kaufert	Do.	Do.
T. Schantz-Hansen	Do.	Do.
A. E. Schneider	Do.	Do.
H. J. Sloan	Do.	Agric. Experiment Sta.

Universities and Colleges (Cont.)

Maurice Day	Michigan State College, Dunbar Forest Exp. Sta.	
James E. Kuntz	University of Wisconsin, Plant Pathology Dept.	
K. R. Shea	Do.	Do.

Chemical Industries

R. H. Beatty	American Chemical Paint Co.,	Ambler, Pa.
T. K. Pavlychenko	Do.	Saskatoon, Sask.
F. R. Sherwood	Do.	Minneapolis, Minn.
L. L. Coulter	Dow Chemical Co.,	South Haven, Mich.
Herbert Zuhl	Do.	Minneapolis, Minn.
J. T. Harvey	Lyon Chemical Co.,	St. Paul, Minn.
Herman Otto	E. I. duPont deNemours & Co.,	Minneapolis, Minn.
J. E. Prendergast	Do.	Do.
F. W. Traugott	Do.	Do.

State Agencies

Earl J. Adams	Minnesota Conservation Dept.,	Div. of Forestry
Sig. Bjerken	Minnesota Dept. Agriculture, Dairy & Food,	Weed Inspector
A. W. Buzicky	Minnesota State Entomologist's Office	
B. C. Jenkins	Michigan Conservation Dept.,	Game Division
Norman Smith	Do.	Forestry Division
Virgil E. Findell	Minnesota Iron Range Resources & Rehabilitation	
B. M. Granum	Do.	
E. A. Schoen	Do.	

County Agencies

L. R. Beatty	Land Commissioner	St. Louis County, Minn.
A. H. Frick	County Agent	Itasca County, Minn.
C. H. Godfrey	Land Commissioner	Do.

U. S. Forest Service

John L. Arend	Lake States Forest Exp. Sta.,	East Lansing, Mich.
M. B. Dickerman	Do.	St. Paul, Minn.
M. L. Heinselman	Do.	Grand Rapids, Minn.
F. R. Longwood	Do.	Marquette, Mich.
J. A. Mitchell	Do.	St. Paul, Minn.
J. R. Neetzel	Do.	Do.
E. I. Roe	Do.	Grand Rapids, Minn.
Paul O. Rudolf	Do.	St. Paul, Minn.
J. H. Stoeckeler	Do.	Rhinelander, Wis.

U. S. Forest Service (Cont.)

Dan E. Bulfer	Nicolet National Forest, Rhinelander, Wis.
Howard C. Cook	Regional Office, Milwaukee, Wis.
P. J. Fassett	Chippewa National Forest, Cass Lake, Minn.
Louis C. Hermel	Do. Do.
David N. Kee	Superior National Forest, Duluth, Minn.
H. L. Sundling	Do. Do.
B. M. Stout	Ottawa National Forest, Ironwood, Mich.

U. S. Bureau of Indian Affairs

Samuel C. Carey	Red Lake, Minn.
C. T. Eggen	Shawano, Wis.
Wm. Heritage	Regional Office, Minneapolis, Minn.
C. F. Peick	Do. Do.
C. H. Racey	Ashland, Wis.
W. J. Ridlington	Shawano, Wis.

U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering

Ralph L. Anderson	Division of Forest Pathology, St. Paul, Minn.

U. S. Bureau of Entomology and Plant Quarantine

John K. Kroeber	Regional Office, Minneapolis, Minn.
L. W. Melander	Do. Do.
Henry N. Putnam	Do. Do.
L. B. Ritter	Do. St. Paul, Minn.

U. S. Fish and Wildlife Service

R. W. Burwell	Regional Office, Minneapolis, Minn.
L. W. Krefting	Research Branch, St. Paul, Minn.
Clair T. Rollings	Regional Office, Minneapolis, Minn.

Other

C. S. Carl	Minneapolis, Minn.
Malcolm Manuel	Triangle Aviation, Inc., Stanton, Minn.
J. McCartney	Northland Chemical Co., St. Paul, Minn.
O. E. Thorbeck	Agricultural Service, Minneapolis, Minn.